MACHINE DESIGN

October 1951

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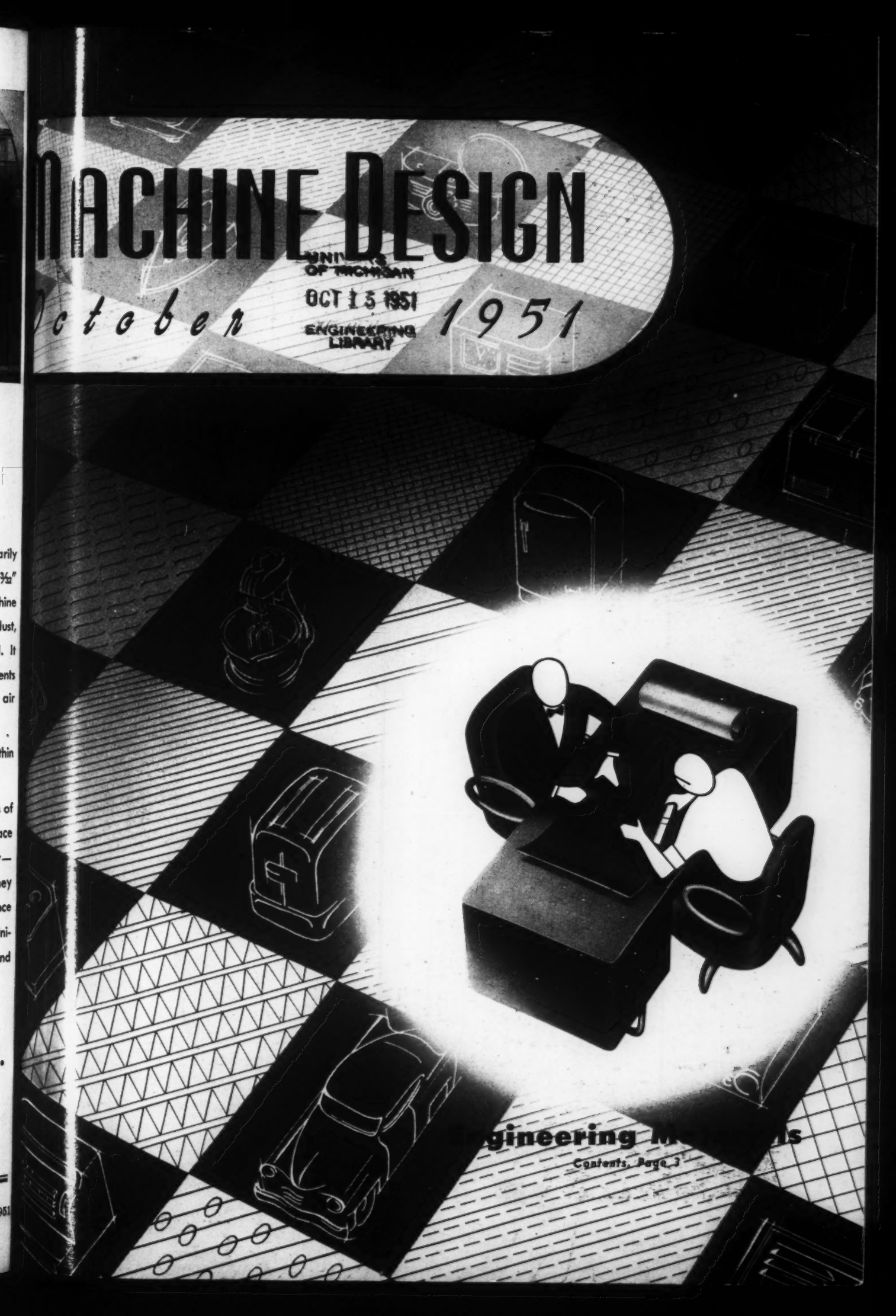

Engineering Materials

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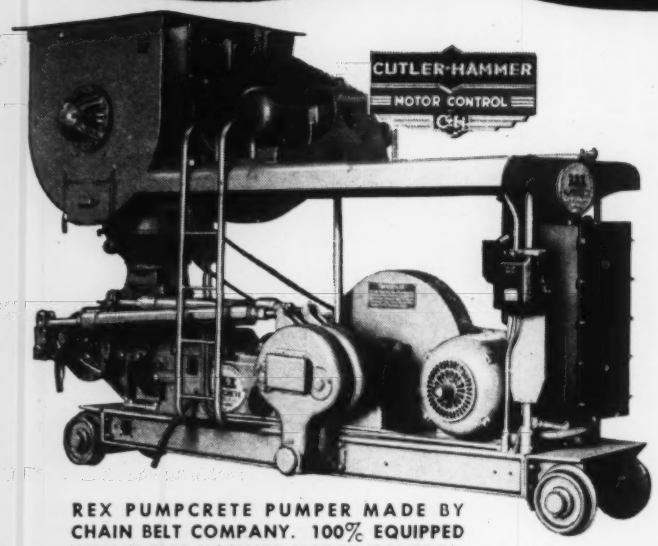

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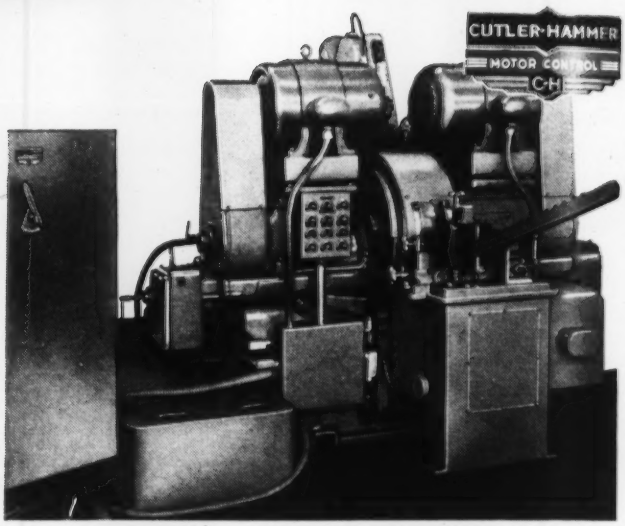

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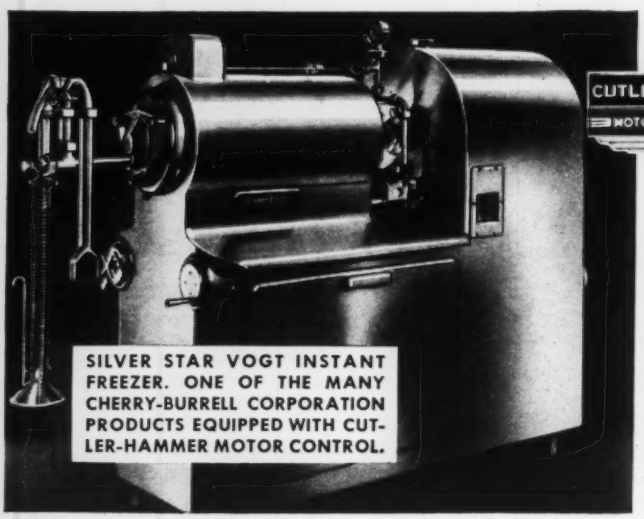

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MACHINE DESIGN

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

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Over the Board

Engineers as Authors

What proportion of engineers contribute to the general advancement of the art and science of enginering by writing articles for technical journals or preparing papers for presentation to their professional societies? We are indepted to one of our good readers, who has also authored or coauthored articles for MACHINE DESIGN, for some figures relating to his own, rather large, organization. A study over a four-year period revealed that in any one year only one engineer in forty-five wrote an article or paper. Putting it another way, the average engineer writes an article once in forty-five years. How about your own organization? Can you improve on this one-in-forty-five ratio?

This Month's Cover

For an appealing cover suggesting the theme of this issue, "Designing With Modern Materials," Penton artists George Farnsworth and Art Bouhall have turned to the chessboard for an idea. The "chessmen" on the dark squares are the machines and appliances which the engineer designs, while the intermediate squares show the standard cross-hatching code for the different engineering materials. The two design engineers are playing no chess game, however. They are busily engaged in selecting and specifying the right material for the job—matching the material to the function.

The Salary Plateau

In a recent Editorial entitled "A Good Place to Work" we lent our support to a plan for according special privileges to engineers who have done and are doing an excellent job but who have reached a salary plateau through the simple fact that there is a ceiling price tag on their jobs. Commenting on the subject, Robert R. Dall aptly remarks: "The salary plateau is a real problem. If nothing else, we ought to landscape it a little to make living there more enjoyable."

Modern Materials

With this issue we are including a special feature on "Designing With Modern Materials," beginning on Page 253. The 60-page article section in this magazine-within-a-magazine is the work of associate editors Roger Bolz and Ben Hummel with the collaboration of materials producers across the country. It replaces the Directory of Materials which has been appearing each October for many years. In the light of the current materials situation we feel that this comprehensive roundup of the latest information on engineering materials and their potentialities in design will serve today's needs more effectively. Like other editorial features in MACHINE DESIGN, this entire section will be available separately to readers. You may obtain single copies for your files so long as the supply lasts by simply filling in one of our return postcards.

An Engineer Defined

It's an old definition, but it bears repeating if only to demonstrate that engineers, for all their shortcomings, do not take themselves too seriously. It comes to us by way of the Engineering Society of Pennsylvania and the Cleveland Engineering Society:

An engineer is a person who passes as an exacting expert on the basis of being able to turn out with prolific fortitude infinite strings of incomprehensible formulas calculated with micrometric precision from vague assumptions which are based on debatable figures taken from inconclusive experiments carried out with instruments of problematical accuracy by persons of doubtful reliability and questionable mentality for the avowed purpose of annoying and confounding a hopeless chimerical group of fanatics referred to, all too frequently, as engineers.

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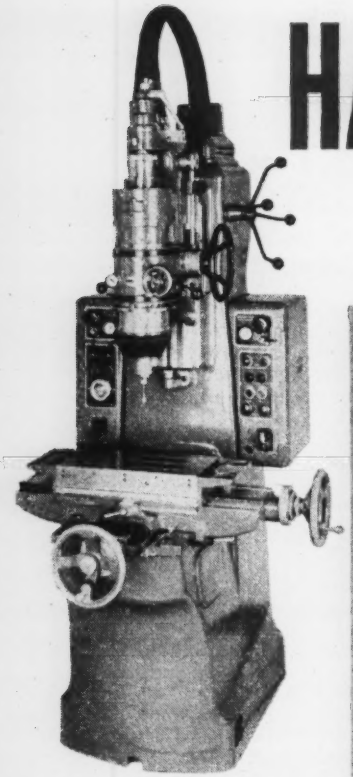
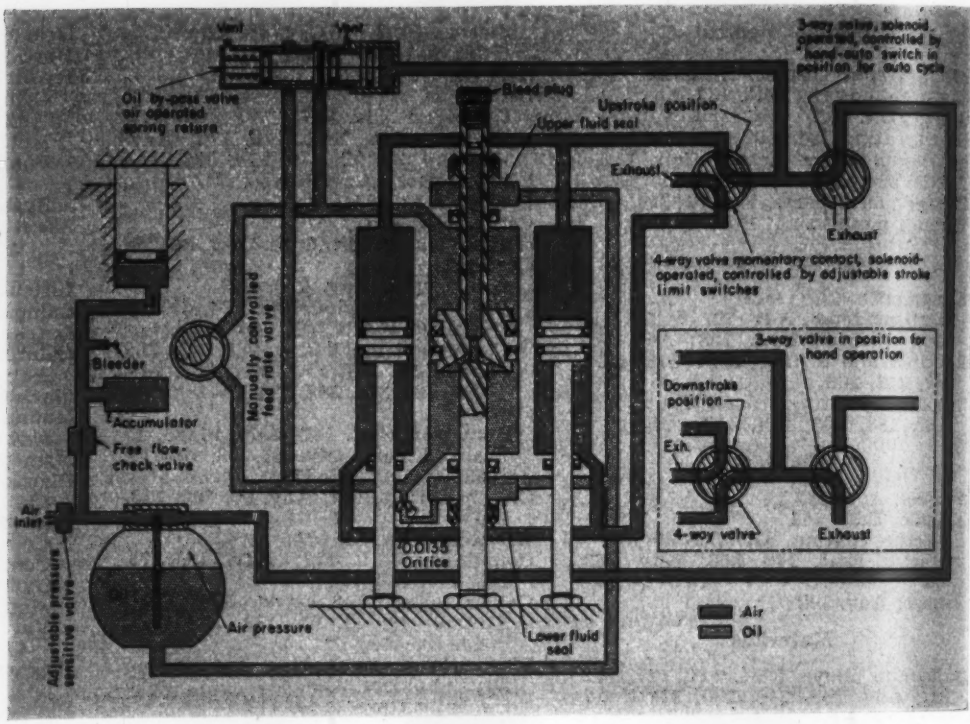
HANNA ELECTRIC VALVE

PROVIDES FOR JIG GRINDER RECIPROCATING ACTION



JIG GRINDER *developed by the Moore Special Tool Company of Bridgeport, Conn., for precision contour and hole grinding.*



THE SCHEMATIC DIAGRAM above shows the circuit used in the Moore Jig Grinder. Power to raise and lower the grinding head is supplied by two Air Cylinders controlled by a Hanna 4-way, double-solenoid valve. This valve, actuated by limit switches, provides the exacting cylinder control necessary for automatic reciprocating movement.

A Hanna Electric Valve was chosen for this application because of its careful manufacture and unusual features. Among these is the tiller principle of operation which eliminates the need for air pressure to initiate the reversing mechanism. This principle involves a short movement of a low mass resulting in maximum speed of operation with minimum shock. The time required for each reversal of the valve is limited to approximately 1/60 second, and its feature of momentary contact (double-solenoid models) eliminates the necessity for a holding current providing an ideal valve for limit switch actuation.

The Hanna Electric Valve is precision-engineered—capable of meeting the most exacting demands. It is an example of the quality characteristic of the complete Hanna line of valves and cylinders. For the finest component parts in the machines you design and build, specify Hanna products—they will measure up to your highest standards.

Hanna Electric Valve . . . balanced spool type . . . controlled by solenoid pilot valve and built-in pilot pistons . . . spools stop against Neoprene cushions for silent action . . . solenoid stroke only 5/32" . . . low current consumption enables use of lighter, more economical contactors, relays, etc. . . . available with either single or double heavy-duty solenoids.

For more detailed information on Hanna Electric Valves and Hanna Hand, Foot and Pilot Operated Valves, send for **Catalog 254.**

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Whence Engineering Manpower?

FIGURES released recently by the engineering manpower commission of Engineers Joint Council paint a discouraging picture of continuing shortages: "Before the war nearly 6 per cent of the boys graduating from high school entered engineering colleges. Now the rate has dropped to 4.8 per cent. About 10 per cent would be needed to meet peacetime civilian needs alone."

First and most immediate need is to concentrate the talents of engineers now available where they can be most effectively used. The EJC urges this four-point program for immediate adoption by industry:

1. Use engineers in jobs in which engineers *only* are required
2. Do not hold young engineers in "intern" positions longer than necessary to qualify them
3. Move engineers to positions of maximum responsibility compatible with ability and experience
4. Release engineers from positions not requiring engineering training.

These points may seem rather obvious, especially to engineering executives who already are following such policies, but to guard against the accusation of "hoarding" engineers management may find a periodic check of the list very much in order.

To these four we would add a fifth, most essential, step: Pay engineers salaries commensurate with their training and responsibilities. So long as engineering salaries are out of line with earnings in other professions and in business, industry cannot expect to hold competent men in engineering jobs or to attract promising young men into the profession.

Adoption of these five steps by industry, plus co-operation from draft boards and the armed services, should start a chain reaction which will ultimately resolve all our engineering manpower difficulties. Thus, utilizing engineers more effectively will not only conserve manpower now but will also permit paying them the higher salaries which are essential. This in turn will make the engineering profession more attractive to youngsters with scientific and mechanical bent so that the future supply of new engineers will be assured.

In the struggle against dictator nations our economic and military survival is vitally dependent upon engineers, but so long as we, a free nation, permit people to choose their own calling we can obtain our engineering manpower only by providing adequate incentives.

Colin Carmichael

EDITOR

PRODUCTION PROCESSES

THEIR INFLUENCE ON DESIGN

Heat Treating

By Roger W. Bolz

Associate Editor, Machine Design

ALTHOUGH the selection and specification of heat treatments is seldom considered too seriously as a vital part in the overall production-design picture, these factors are important and can often have a tremendous effect on final costs. Because it would be amiss to overlook this area in design, it should be covered in detail as it affects design. However, owing to the tremendous scope of the subject only the most common treatments for steels can be covered; those specialized and more limited in scope of necessity are omitted.

Conditioning Processes. In a large number of instances, some type of treatment is usually necessary to condition steels either before or after processing of any kind. Processes for conditioning metals therefore assume an important place in the design procedure. True, the treatment of metal for desirable properties may have no effect whatsoever on the actual problem of mechanical or functional design; but, again, it may have a considerable effect. The designer should at least be aware of the general problem in order to cope intelligently with it prior to actual release for production.

As a rule, all heat treatments accomplish one of two purposes: (1) Soften the metal or (2) harden the metal. These results can be achieved by differing means and with different metals or designs, specific treatments are most economical or most satisfactory.

Softening Treatments. In general, there are the following most commonly used methods or treatments designed for softening or altering the structure of the metal:

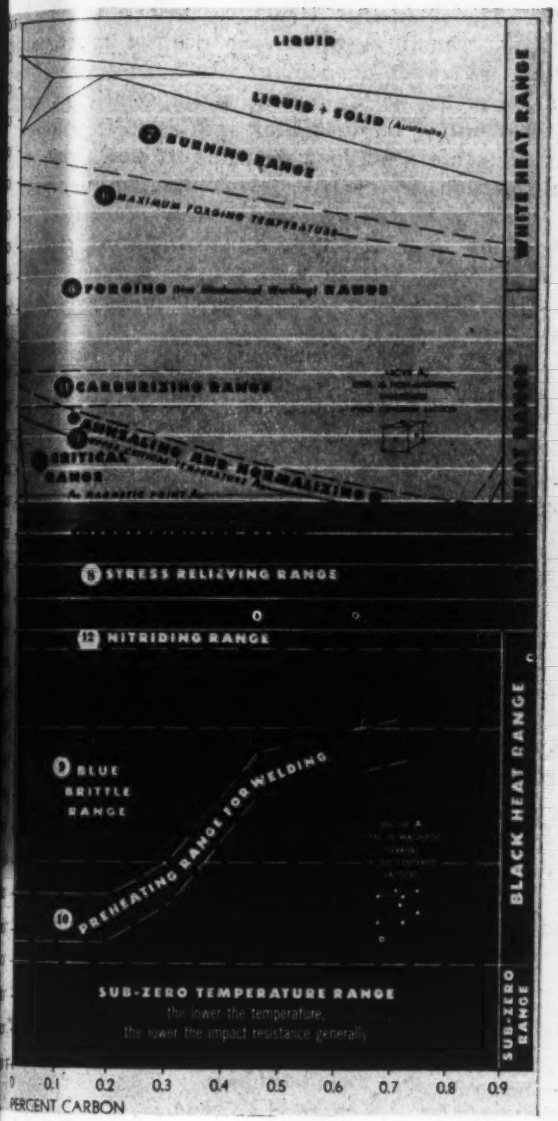
1. Annealing
2. Normalizing
3. Stress Relieving.

These treatments, as contrasted with hardening methods, are of the nonquenching type, only controlled heating and cooling being utilized.

ANNEALING. This treatment consists of heating above the Ac_3 or critical temperature of the metal, followed by controlled furnace cooling to below the Ar_1 or transformation-end temperature. It is used to condition the metal so it is most suitable for machining and other cold finishing processes. The chart in *Fig.* 1 shows graphically the various temperatures required with different steels. Annealing for machinability is needed with most steels other than those specifically designed to be free-machining, especially with steels over 0.35 to 0.40 per cent carbon.

General rules for suitable annealing treatments for all steels to obtain optimum machinability are difficult to specify. In many cases, however, certain procedures have proved desirable. These might be outlined for the particular type of processing as in the following:

This article is based on Chapter 55 of the author's forthcoming book *Production Processes—Their Influence on Design*, Penton Publishing Co., Cleveland, 1951.



Photo, courtesy Tempil Corp.

1. **CRITICAL RANGE.** In this range steels undergo internal changes which radically affect the properties of the material.
2. **LOWER CRITICAL TEMPERATURE (A_1).** Termed Ac_1 on heating, Ar_1 on cooling. Below Ac_1 structure ordinarily consists of ferrite and pearlite (see below). On heating through Ac_1, the solid ferrite and the solid pearlite begin to dissolve in each other to form austenite (see below) which is nonmagnetic. This dissolving action continues on heating through the critical range until the solid solution is complete at the upper critical temperature.
3. **UPPER CRITICAL TEMPERATURE (A_3).** Termed Ac_3 on heating, Ar_3 on cooling. Above this temperature the structure consists of austenite which coarsens with increasing time and temperature. Upper critical temperature is lowered as carbon increases to 0.85 per cent (eutectoid point).
4. **ANNEALING** consists of heating steels to slightly above Ac_3, holding for austenite to form, then slowly cooling in order to produce small grain size, softness, good ductility and other properties. On cooling slowly the austenite transforms to ferrite and pearlite.
5. **NORMALIZING** is similar to annealing except that cooling is done in still air. On cooling, austenite transforms giving somewhat higher strength and hardness and slightly less ductility than in annealing.
6. **FORGING RANGE** extends to several hundred degrees above the upper critical temperature.
7. **BURNING RANGE** is above the forging range. Burned steel cannot be cured except by remelting.
8. **STRESS RELIEVING** consists of heating to a range definitely below the lower critical temperature, holding for one hour or more per inch of thickness, then slowly cooling. Purpose is to allow the steel to relieve itself of locked-up stresses.
9. **BLUE BRITTLE RANGE** occurs approximately at 300 to 700 F, in which range steels are more brittle than above or below this range. Peening or working of steel should not be done in this range.
10. **PREHEATING FOR WELDING** is carried out to prevent crack formation.
11. **CARBURIZING** consists of dissolving carbon into surface of steel by heating to above critical range in presence of carburizing compounds.
12. **NITRIDING** consists of heating certain special steels to about 1000 F for long periods in the presence of ammonia gas. Nitrogen is absorbed into the surface to produce extremely hard "skins."
13. **SPHEROIDIZING** consists of heating to just below the critical range to put the cementite constituent of pearlite in globular form. This produces softness and in many cases good machinability.

FERRITE is practically pure iron (in plain-carbon steels) existing below the lower critical temperature. It is magnetic and has very slight solid solubility for carbon.

AUSTENITE is the nonmagnetic form of iron and has the power to dissolve carbon and alloying elements.

CEMENTITE or iron carbide is a chemical compound of iron and carbon Fe_xC.

PEARLITE is a lamellar mechanical mixture of ferrite and cementite.

BAINITE is formed when austenite decomposes at temperatures between 1025F and 350F.

EUTECTOID STEEL contains approximately 0.85 per cent carbon.

MARTENSITE is an extremely hard constituent of steels, formed by the rapid transformation of austenite.

Fig. 1—Overall chart showing the general treatment picture for steels. Terms shown are defined briefly

1. *Rough metal removal.* Where removal of metal requires little accuracy or fine finish, the softest obtainable condition of coarsely spheroidized microstructure, having a hardness as low as 80 Rockwell B, offers least resistance. Somewhat higher hardnesses with accompanying partially spheroidized lamellar or a coarse lamellar structure offer better chip formation
2. *Broaching.* Medium to fine lamellar microstructures with hardnesses of 91 to 102 Rockwell B have proved well suited to broaching operations
3. *General-purpose machining.* A medium to coarse lamellar structure is preferred for general-purpose machining operations. Structures showing up to 50 per cent spheroidization are good and hardnesses generally range from 87 to 98 Rockwell B, depending upon the type of steel and structure
4. *Cold working.* Anneals for cold forming, upsetting or heading operations may vary considerably. Depending upon the amount of working required, the metal may range from fairly high hardnesses to dead soft. Maximum working, of course, requires maximum softness.

NORMALIZING. Parts which have been hot worked and allowed to cool in air such as found with forging, rolling, upsetting, etc., usually have nonuniform structures, grain size, and hardness. To eliminate distortion, achieve uniform structure, uniform response to heat treatment, etc., a normalizing treatment is used. As the term indicates it is principally designed to achieve a "norm" or uniformity. It consists of heating to at least 100 F above Ac_3 and cooling in still air to room temperature.

STRESS RELIEVING. Cold working or work done at any temperature below about 1425 F induces internal stresses which, unless eliminated, frequently create difficulties in subsequent processing operations. Stress relieving is virtually a subcritical anneal, the steel being heated to a temperature below Ac_1 and allowed to cool slowly in air. It is particularly applicable after straightening and machining operations and before or after heat treatments to obviate distortion.

Hardening Treatments. To improve the physical properties of medium and higher carbon content steels, as well as alloy steels, over that of low-carbon common garden-variety steels, heat treatments to increase hardness are utilized. Hardening is accomplished in several ways and steps:

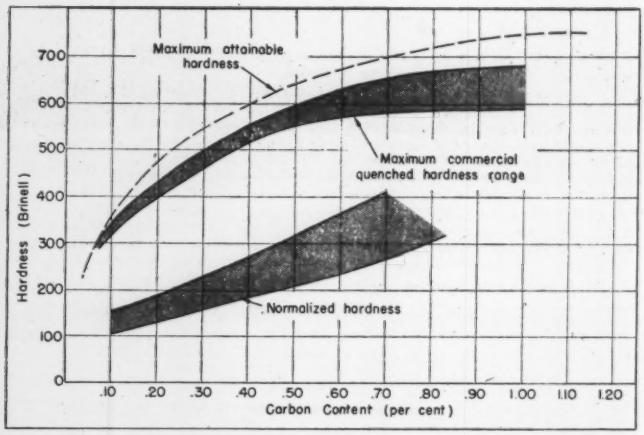


Fig. 2—Approximate relationship between carbon content and maximum hardness attainable and normalized hardness. Size, alloy content and rate of cooling all affect final hardness and hence values are only relative

1. By heating to austenitizing temperature (above Ac_3) and quenching or continuously cooling to room temperature in air, oil, water, molten chemical or metallic salts, or other liquid or gaseous media
2. By heating and interrupting the quench
3. By conventional or interrupted quenching and tempering.

As contrasted with softening treatments, hardening methods are generally of the quenching type and the effectiveness of the quench in producing hardness is a direct function of the carbon content of the steel,

Table 1—Carburizing Case Depths*

(inches)

Time (hours)	Temperature (F) 1400	1450	1500	1550	1600	1650	1700	1750	1800	1850
1.....	0.008	0.010	0.012	0.015	0.018	0.021	0.025	0.029	0.034	0.040
2.....	0.011	0.014	0.017	0.021	0.025	0.030	0.035	0.041	0.048	0.056
3.....	0.014	0.017	0.021	0.025	0.031	0.037	0.043	0.051	0.059	0.069
4.....	0.016	0.020	0.024	0.029	0.035	0.042	0.050	0.059	0.069	0.079
5.....	0.018	0.022	0.027	0.033	0.040	0.047	0.056	0.066	0.077	0.089
6.....	0.019	0.024	0.030	0.036	0.043	0.052	0.061	0.072	0.084	0.097
7.....	0.021	0.026	0.032	0.039	0.047	0.056	0.066	0.078	0.091	0.105
8.....	0.022	0.028	0.034	0.041	0.050	0.060	0.071	0.083	0.097	0.112
9.....	0.024	0.029	0.036	0.044	0.053	0.063	0.075	0.088	0.103	0.119
10.....	0.025	0.031	0.038	0.046	0.056	0.067	0.079	0.093	0.108	0.126
11.....	0.026	0.033	0.040	0.048	0.059	0.070	0.083	0.097	0.113	0.132
12.....	0.027	0.034	0.042	0.051	0.061	0.073	0.087	0.105	0.119	0.138
13.....	0.028	0.035	0.043	0.053	0.064	0.076	0.090	0.106	0.123	0.143
14.....	0.029	0.037	0.045	0.055	0.066	0.079	0.094	0.110	0.128	0.149
15.....	0.031	0.039	0.047	0.057	0.068	0.082	0.097	0.114	0.133	0.154
16.....	0.032	0.039	0.048	0.059	0.071	0.084	0.100	0.117	0.137	0.159
17.....	0.033	0.040	0.050	0.060	0.073	0.087	0.103	0.121	0.141	0.164
18.....	0.033	0.042	0.051	0.062	0.075	0.090	0.106	0.125	0.145	0.169
19.....	0.034	0.043	0.053	0.064	0.077	0.092	0.109	0.128	0.149	0.173
20.....	0.035	0.044	0.054	0.066	0.079	0.094	0.112	0.131	0.153	0.178
21.....	0.036	0.045	0.055	0.067	0.081	0.097	0.114	0.134	0.157	0.182
22.....	0.037	0.046	0.056	0.069	0.083	0.099	0.117	0.138	0.161	0.186
23.....	0.038	0.047	0.058	0.070	0.085	0.101	0.120	0.141	0.164	0.190
24.....	0.039	0.048	0.059	0.072	0.086	0.103	0.122	0.144	0.168	0.195
25.....	0.039	0.049	0.060	0.073	0.088	0.106	0.125	0.147	0.171	0.199
26.....	0.040	0.050	0.061	0.075	0.090	0.108	0.127	0.150	0.175	0.203
27.....	0.041	0.051	0.063	0.076	0.092	0.110	0.130	0.153	0.178	0.206
28.....	0.042	0.052	0.064	0.078	0.094	0.112	0.132	0.155	0.181	0.210
29.....	0.042	0.053	0.065	0.079	0.095	0.114	0.134	0.158	0.185	0.214
30.....	0.043	0.054	0.066	0.080	0.097	0.116	0.137	0.161	0.188	0.217

* From F. E. Harris, *Metal Progress*, August, 1943.

Fig. 2. The austenitic structure formed above Ac_1 *Fig.* 1, is transformed into the desired martensitic structure by rapid quenching, which suppresses the formation of the softer ferritic and cementitic forms. To permit milder oil quenching and less distortion, alloying elements are added to steels to slow down the transformation and thus control the depth and severity of the hardening.

Depending upon the type of steel, differing treatments are employed to achieve the most desirable type of hardened condition. Those commonly used are generally:

1. Case hardening
2. Surface hardening
3. Through hardening.

CASE HARDENING. Hardening of a surface layer of a steel part, by essentially the addition of carbon or nitrogen, may be accomplished by one of several different methods. These case hardening processes are:

1. Carburizing
2. Cyaniding
3. Carbonitriding
4. Nitriding.

Carburizing. This is a process whereby carbon is added to the outer layer of a steel part, within limitations, and the piece is quench hardened. Generally, the steels employed are initially low in carbon content. The methods of adding carbon in carburizing can be classified as pack, gas and liquid. Amount and depth of case is generally a function of temperature and time, TABLE 1. Greatest degree of control is found with gas carburizing and maximum depth also is provided by the gas-diffusion method. Deep cases of 0.300 to 0.400-inch are practicable by this diffusion process.

Cyaniding. The cyaniding method provides a superficial case of good wear resistance and high hardness. Generally, this consists of heating the parts in a molten bath of cyanide salts and following with quenching. Usual immersion periods are from one-half to one hour. Nitrogen produced by decomposition of the bath produces iron nitrides in the case and these impart the high hardness.

Carbonitriding. A combination of nitrogen and carbon is added to the surface by heating in a suitable gaseous atmosphere and quenching. A modified carburizing process, this method effects lower costs where volumes are large and creates less distortion than carburizing. However, case thickness produced is limited and seldom exceeds 0.030-inch.

Nitriding. This process consists of adding nitrogen to the surface by heating, in a suitable

Fig. 3—Take-off drive shaft of SAE 4140 steel flame hardened to 59 Rockwell C on the spline

Fig. 4 — Automatic flame hardener used in treating the splined shaft shown in *Fig. 3*

Photo, Courtesy Cincinnati Milling Machine Co.

gas atmosphere, alloy steels capable of assimilating the nitrogen. No quenching is required, the hardness being produced by the nitrides formed from the combination of nitrogen, iron and alloying elements. Special Nitralloy steels are generally used. With chromium-aluminum-molybdenum steels a 50-hour cycle will produce a 0.015-inch case of which 0.005 to 0.007-inch exceeds 900 Vickers in hardness. A 100-hour cycle will produce a case of 0.030-inch with 0.010 to 0.012-inch in excess of 900 Vickers hardness. With large sections, normalizing prior to heat treating is recommended, the heat treating being necessary for best nitriding results.

SURFACE HARDENING. Where moderately hard surfaces are satisfactory, rapid surface hardening of medium-carbon steels can be highly economical. This can be accomplished by flame or induction hardening. Rapid heating of the steel by flames or high-frequency current is followed by quenching. Advantage besides speed is extremely low distortion on symmetrical parts.

Flame Hardening. Where extremely high hardnesses are not necessary superficial hardening of the surface of medium and high-carbon steels may be accomplished by flame hardening, *Fig.* 3. This method merely consists of rapidly heating the surface by means of a torch or torches and quenching by spray or immersion. Apparatus may be simple or elaborate, *Fig.* 4. Parts flame hardened may or may not have a previous heat treatment. Many parts, however, are first conventionally heat treated.

Induction Hardening. In a manner similar to that of flame hardening, induction hardening produces a superficial surface effect, *Fig.* 5. Electrical frequencies from 1000 to 500,000 cycles are employed and, for heating, special fitted induction coils are necessary. For simple or uniform parts, coils are no problem but where intricate or unusual parts are concerned, induction coils may prove difficult.

THROUGH HARDENING. To obtain throughout a given part the optimum in mechanical properties—adequate strength together with the greatest tough-

Photo, courtesy Ohio Crankshaft Co.

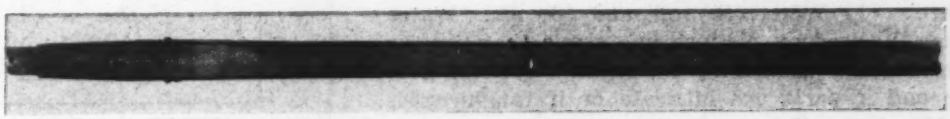


Fig. 5—Salisbury axle induction hardened full length on Tocco machine. Surface is hardened to 55 Rockwell C 1/8-inch deep and subsequently drawn back to 43 to 47. Use of SAE 1033 with flame hardening instead of SAE 4140 and conventional treatment reduced material costs, permitted machining prior to hardening, and cut machining time by 75 per cent

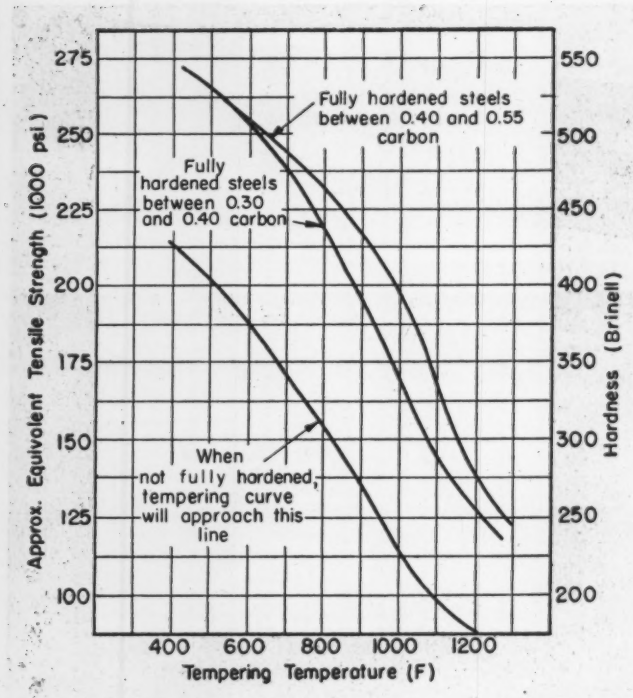


Fig. 6—Typical curves showing relation between hardness and tempering temperatures *(SAE Handbook)*

ness possible at that strength—through hardening is normally employed. This usually consists of heating to some point above the critical temperature and quenching. In the interests of toughness, tempering or drawing back is used immediately following the quench. Alloy steels are often necessary to obtain the desired hardening and, especially where sections vary widely, some compromise may be desirable to avoid brittle-hard sections.

Tempering. To achieve the degree of toughness desired in a piece after quenching, tempering is generally desirable. The operation consists primarily in reheating a part after hardening to a low or moderately high temperature and cooling. This serves to "draw back" somewhat on the hardness, *Fig.* 6, but must normally be done to achieve a degree of toughness or plasticity necessary to resist fatigue and cracking. A general rule-of-thumb is that a part must be held at drawing heat for one hour per inch of cross section to insure thorough heating.

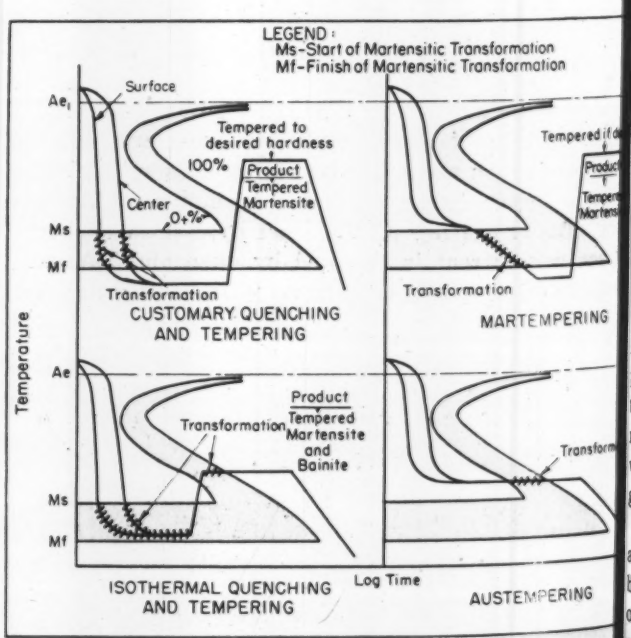
Quenching. A number of quenching media are employed for through hardening depending upon the part, the steel used and the design. The common ones are: (1) Water, (2) oil, and (3) air. Water is generally used on plain-carbon steels that require fast cooling to attain top hardness. Quenching is severe and if parts are intricate or if toughness is desirable, oil should be used.

The oil quench is probably most widely used, especially with alloy steels. The greater sensitivity of alloy steels to hardening necessitates this milder quench and, being slower, the quench induces less distortion. Cooling in an air blast is used with highly alloyed (tool) steels. Minimum hardening distortion with maximum hardness makes these steels ideal where the low distortion can be justified economically.

Interrupted Quenching. Generally applied to medium and high-carbon steels, these processes are designed to reduce distortion and cracking in the hardening treatments. Three interrupted-quench treatments used are: (1) Martempering, (2) austempering and (3) isothermal. In martempering the operation is designed to equalize temperature gradients within parts before the structure transformation progresses very far. A part is quenched into a molten salt, or a high flash point oil, at a temperature approximately the *Ms* point (martensitic transformation starts) of the steel (300 to 500 F) and held until the entire mass has reached bath temperature. This is followed by cooling to room temperature in air.

Parts with substantial differences in mass or complicated design are particularly subject to growth, shrinkage and twisting distortion. With steels of high hardenability, cracking may take place. Generally, these factors are caused by the unequal stresses created during rapid austenite-martensite transformation (see discussion under hardening treatments) occurring at different times in different portions of a part. Martempering obviates to a great extent these factors. About 3 to 4 inches is the usual maximum section which can be fully hardened.

Austempering is somewhat similar to martempering in purpose but has found most use with plain-carbon steels and with alloy steels in the lower alloy content range. The quench is generally a molten salt or molten low melting alloy and the parts are quenched direct from heat treating temperature. However, by holding the bath at 400 to 700 F the martensitic structure which forms at lower temperatures is avoided and only the structure bainite forms. The process is



Drawings, courtesy U. S. Steel Corp.

Fig. 7—Diagrammatic charts showing the comparative characteristics of the various tempering processes

particularly suited for relatively light sections generally less than ½-inch and seldom over 1 inch in thickness. An additional asset is found in the unusual toughness of parts which are austempered. Hardnesses range from 48 to 58 Rockwell C or about the same as a piece tempered in the range of 450 to 650 F but accompanying toughness is much greater.

Isothermal quenching consists of cooling in an agitated salt bath, at 400 to 600 F, until temperature is equalized and transferring to a bath at a higher heat to draw the part. This treatment is generally used for obtaining physicals similar to those from austempering but in larger sizes. Sections up to 2 inches can generally be handled. Diagrammatic pictures of these quenching processes are shown in *Fig.* 7.

Design Considerations

In general, the most important consideration in the design of parts to be heat treated is the effect of the design configuration on the success of the treatment in production. Extremely intricate parts naturally are potentially troublesome to handle as are parts with widely varying sections or masses, *Fig.* 8. The problem, therefore, becomes one of selecting a steel and a treatment compatible with the necessary design, which will offer adequate results. The results, of course, would be in terms of strength, toughness, wear resistance, and maximum retention of accuracy. The final, but not least, consideration is that of reasonable or satisfactory cost.

Service Requirements. A practical approach to selection and specification of the most desirable heat treatment would be by means of service properties. These may be subdivided into several categories:

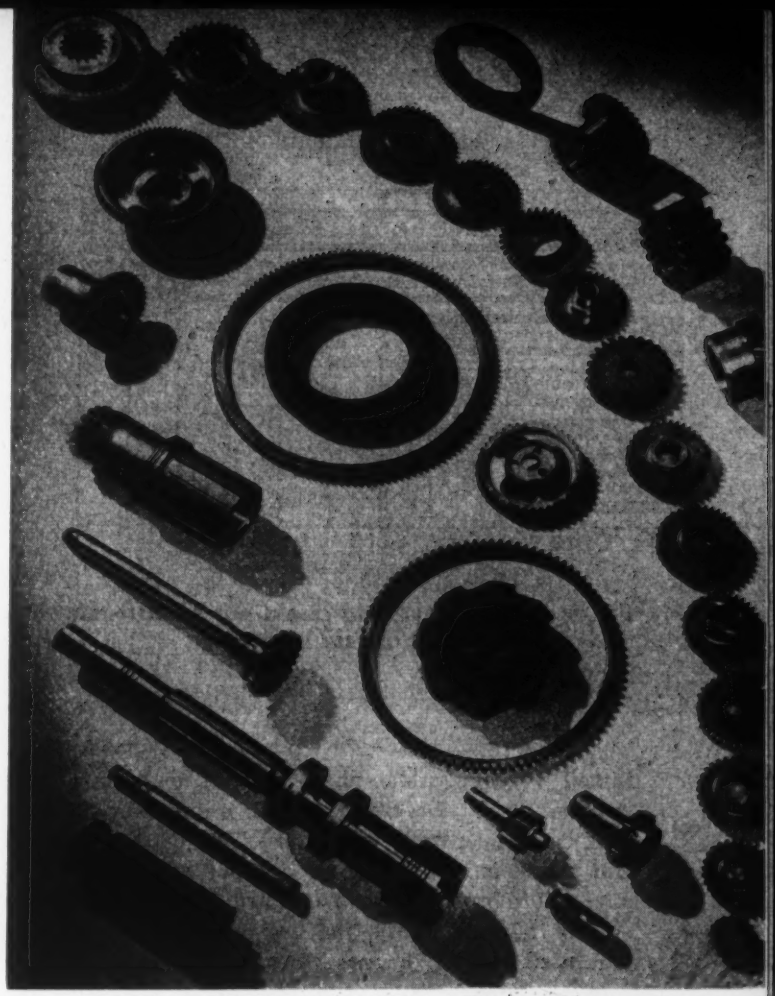
1. Hard. Resistance to wear and indentation
2. Tough. Resistance to torque, impact, fatigue or pull
3. Hard and tough. Any combination of hardness and toughness.

Service requirements for a specific machine part or parts will generally indicate the category and also help determine the most likely steel to use.

HARDNESS. In the interests of hardness, generally one of the following treatments is employed: (1) Case hardening, (2) surface hardening, or (3) through hardening. Case hardening is perhaps the most common for obtaining hardness only. Generally, low-carbon steels with carbon contents under 0.25 per cent are used but where distortion is a problem the alloy grades are preferable. Alloy grades also result in a more uniform and generally harder case with sections over 3 or 4 inches than do plain-carbon grades.

Hardness and wear resistance of the nitrided case are superior, and the cyandide, carbonitrided and carburized cases follow in descending order. The chart of *Fig.* 9 gives an idea as to the general ranges possible with the various case hardening processes.

Depth of case required must be adequately considered. Where excessive shock and pressures are negligible, depth of case depends upon the distortion that may occur and on such factors as grinding, wear



Photo, courtesy Cincinnati Milling Machine Co.

Fig. 8—Group of flame hardened machine parts exhibiting widely varying sections and intricacy

permissible, etc. The process to use and specifications to call for must therefore be predicated to a great extent upon the part design in the interests of obviating distortion. Drawing specifications may be selected from the chart of case hardening treatments shown in *Fig.* 10 on the basis of the general design of the part in question. In average cases of pack carburizing an allowance of 0.015 to 0.025-inch is usually made for grinding to take care of distortion. Where distortion is greater, it is usually more economical to select some other process or combination which results in lesser distortion. Typical allowance provided for liquid carburizing is about 0.005 to 0.010-inch although in many instances, distortion can be held to 0.001-inch.

Where hardnesses over 60 Rockwell C are not imperative and values under 55 to 60 are satisfactory, flame or induction hardening can be used, *Fig.* 11. For wear-resistant hardness, plain-carbon steels of 0.40 to 0.50 per cent carbon such as AISI C-1045 or 1050 are satisfactory. Generally, the drawing specification should read:

Machine
Stress relieve (where part is intricate or considerable machining is involved)
Flame (or induction) harden designated surfaces
Temper (where induced stresses may result in undesired distortion; drawing at 400 F reduces stresses 40 to 50 per cent).

With parts where high hardness cannot be ob-

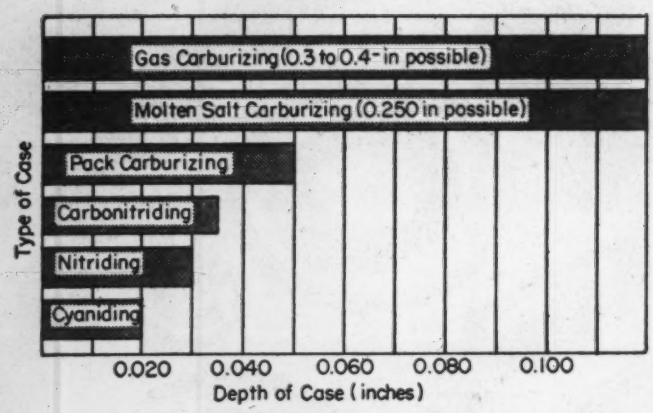


Fig. 9—General ranges in case depth by different methods of case hardening

tained without undue distortion, through-hardening is often used. Plain high-carbon steels over 0.60 per cent carbon (usually AISI C-1080 or C-1090) and oil and water-hardening alloy or tool steels employed also afford greater depth of hardness. In the interests of hardness only, the use of through-hardening is limited and may be less economical.

TOUGHNESS. Through-hardening is generally the major treatment for obtaining toughness. In the interests of maximum toughness only, hardnesses under 300 Brinell are generally specified and alloy steels in the medium-carbon range are employed. Occasionally a low-carbon alloy can be used to advantage.

Most of these steels can be machined in heat-treated condition under 300 Brinell although machinability varies with the analysis and hardness. Generally, machinability is in the following order with the best machining grades first:

1. A-4640
2. A-4145
3. A-8642
4. A-4340
5. A-3140
6. A-5140
7. A-6145
8. A-2345
9. A-3250
10. C-1045

The water-quenching plain-carbon steels distort more than the oil-hardening types and specifications must take this factor into consideration. If parts are long and slender, straightening may be necessary. Such parts should normally have the following specification:

Anneal
Heat treat
Straighten
Stress relieve
Machine.

If the machining involved is considerable, it is desirable to first rough machine to eliminate any great amount of machining after hardening. The specification would be:

Fig. 10—Selector for case hardening specifications. Treatments are arranged to permit lowest production cost compatible with minimum possible distortion

Anticipated Distortion According to Design	Type of Steels AISI			
	Low-carbon C-1020 B-1112 C-1117 etc. (all sizes)	**Low-carbon** C-1020 B-1112 C-1117 etc. (under 3-in.)	**Low-carbon alloys** A-4615 A-3115 A-8620 A-5120 etc. (large sizes)	**Medium-carbon alloys** A-4140 A-4640 etc. Nitralloy
Negligible Distortion **Symmetrical** **Chunky** **Simple**		Machine Carburize (or cyanide) Harden Grind	Machine Carburize (or cyanide) Harden Grind	
Low Distortion		Rough machine Normalize Finish machine Carburize (or cyanide) Harden Grind	Machine Carburize (or cyanide) Harden Grind	
Medium Distortion	Machine Carbonitride Harden Grind		Machine Stress relieve Carburize (or cyanide) Harden Grind Rough machine Normalize Finish machine Carburize (or cyanide) Harden Grind	
Considerable Distortion **Slender** **Long, narrow** **Irregular**			Machine Carbonitride Harden Grind Rough machine Normalize Finish machine Carbonitride Harden Grind Rough machine Normalize Finish machine Carburize Martemper Grind Rough machine Carburize Straighten Finish machine Stress relieve Martemper Grind	Machine Stress relieve Nitride Anneal Rough machine Heat treat Finish machine Stress relieve Nitride Preheat—treat Machine Stress relieve Nitride Preheat—treat Rough machine Stress relieve Finish machine Nitride

Table 2—SAE Classification of Steel Cases and Cores for Hardenability

Low		Medium				High		
		Hardenability Classification						
Case*								
1000	1100		2500	4300		1300	4100	8600
			3300	4800		2300	4600	8700
				9300		4000	5100	
Core								
4017	4608	1320	3120	4621	8620	2517	4820	
4023	4615	2317	4032	4812	8622	3310	9310	
4024	4617	2512	4119	4815	8720	3316	9315	
4027	8615	2515	4317	5115	9420	4320	9317	
4028	8617	3115	4620	5120		4817		

* As original carbon content has no effect on case hardening, last two digits are omitted.

Anneal
Rough machine
Heat treat
Finish machine.

Where the highest range of hardnesses are concerned and the part is of fairly massive shape, distortion would be small and the steps could be:

Anneal
Machine
Heat treat
Grind.

Within the alloy steel grades there is comparatively little difference in physical properties between the medium (A-5140, A-4145, A-8642, etc.) and rich (A-4340, A-3250, etc.) alloys under 300 Brinell hardness. The rich alloys, however, exhibit somewhat better impact strength at the same hardnesses up to 300 Brinell.

HARDNESS-TOUGHNESS. In the hardness-toughness category widely varied combinations are possible. Almost always, the combination is a matter of compromise between the two physical properties. As hardness increases beyond 300 Brinell, toughness or resistance to impact and fatigue decrease to the point where at maximum hardness this property all but disappears.

Case-hardened parts require steels with proper core properties, especially those to be selectively case hardened. Where high compressive loads are encountered, a fairly high core hardness is beneficial in supporting the case. However, if great toughness is the design requirement, a low core hardness may be preferable. Steels tabulated as to both case and core hardening properties are given in TABLE 2. Generally, in order to assure adequate toughness, the case thickness should not exceed more than one-sixth the section thickness. The relationship of case thickness relative to the service expected is shown in *Fig.* 12.

In the range of directly hardenable alloy steels, the breakdown as outlined in *SAE Standards* is extremely helpful in specification. Five groups are set up as follows under mean carbon content in per cent:

1. *Carbon* 0 30 *to* 0.37. For heat-treated parts requiring moderate strength and great toughness. Frequently used for water-quenched parts of moderate section size or oil-quenched parts of small size. Typical parts are connecting rods, axle shafts, studs, steering knuckles, etc.
   Low hardenability—SAE 1330, 1335, 4037, 4042, 4130, 5130, 5132, 8630
   Medium hardenability—SAE 2330, 3130, 3135, 4137, 5135, 8632, 8635, 8637, 8735, 9437
2. *Carbon* 0.40 *to* 0.42. For heat-treated parts requiring higher strength and good toughness. Used for medium and large-size parts, low and medium-hardenability steels being generally employed for axle shafts, propeller shafts and high-hardenability steel for particularly large axles, shafts and aircraft parts. Generally oil quenched.
   Low hardenability—SAE 1340, 4047, 5140, 9440
   Medium hardenability—SAE 2340, 3140, 3141, 4053, 4063, 4140, 4640, 8640, 8641, 8642, 8740, 8742, 9442
   High hardenability—SAE 4340, 9840
3. *Carbon* 0.45 *to* 0.50. For heat-treated parts requiring fairly high hardness and strength along with moderate toughness. Parts are usually gears and similar stressed machine components.
   Low hardenability—SAE 5045, 5046, 5145, 9747, 9763
   Medium hardenability—SAE 2345, 3145, 3150, 4145, 5147, 5150, 8645, 8647, 8650, 8745, 8747, 8750, 9445, 9845
   High hardenability—SAE 4150, 9850

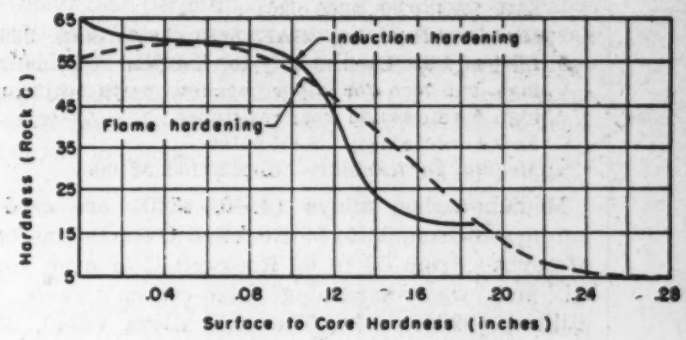


Fig. 11—Graph showing typical hardness curves for flame and induction hardening

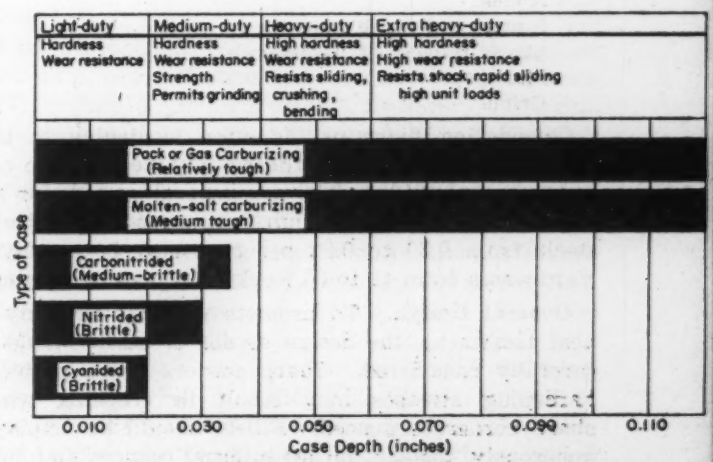


Fig. 12—Chart showing relationship of case thickness to overall service conditions of hard-tough parts

4. *Carbon* 0.50 *to* 0.62. Used primarily for springs and tools.
   Medium hardenability—SAE 4068, 5150, 5152, 6150, 8650, 9254, 9255, 9260, 9261
   High hardenability—SAE 8653, 8655, 8660, 9262
5. *Carbon* 1.02. Used mainly for ball and roller bearings but also for other machine parts requiring high hardness and wear resistance.
   Low hardenability—SAE 50100
   Medium hardenability—SAE 51100, 52100.

Medium-carbon alloys (4140, 4340) are used at hardnesses from 32 to 50 Rockwell C for the majority of parts. From 50 to 60 Rockwell C or over, tough oil and water-hardening high-carbon steels are utilized (9262 etc.). The rich alloys (4340, 2345, etc.) show little or no marked difference in physicals over the medium-alloy group (3140, 4140, etc.) in this hard-tough area unless over 321 Brinell (34 Rockwell C) in hardness and 3½ inches in section.

Owing to the many variations present in this area, it is only possible to suggest practical specifications which can be used effectively, with due consideration to the other factors previously discussed. These can be for parts machined after heat treatment to a hardness of 32 to 38 Rockwell C:

1. *Comparatively chunky or symmetrical design*
   Heat treat
   Machine
2. *Comparatively long or intricate design*
   Heat treat
   Straighten
   Stress relieve
   Machine

For parts to be heat treated to a hardness of 32 to 50 Rockwell C after machining:

1. *Comparatively chunky or symmetrical design*

Anneal	or	Anneal
Machine		Rough machine
Heat treat		Heat treat
Grind		Finish machine
		Grind

2. *Comparatively long or intricate design*

Anneal	or	Anneal
Rough Machine		Rough and finish machine
Heat treat		Stress relieve
Finish machine		Heat treat
Grind		Grind

or

   Anneal
   Rough and finish machine
   Stress relieve (if necessary)
   Martemper
   Grind.

Considering flame or induction hardening in this category, although for hardness only steels in the carbon range of 0.40 to 0.50 are generally used, for applications where hard-tough properties are desirable steels from 0.30 to 0.52 per cent may be employed. Hardnesses from 41 to 63 Rockwell C can be obtained.

General Design. To promote greatest economy in heat treatment, the design details of parts should be carefully considered. Sharp corners are a problem; hardening stresses may result in cracking where sharp corners are used. Fillets should be employed generously, instead, on all internal corners and junctions. Radical changes in section thickness should also be avoided.

Wherever possible, heavy and light sections should

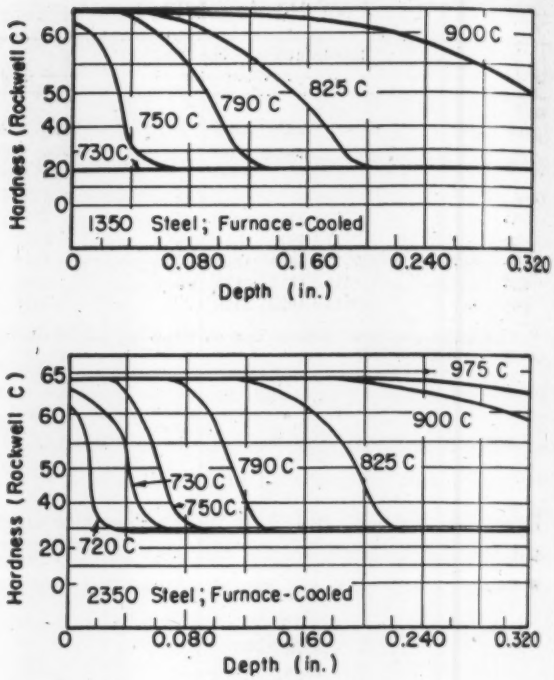


Fig. 13—Groups of penetration curves showing induction hardening characteristics for five steels

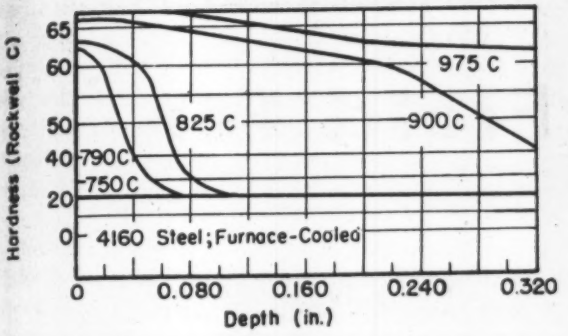
be designed as separate parts to help maintain uniformity in individual pieces. Openings or holes should not be clustered together; wherever practicable such features should be set up to give a balanced layout. If threaded sections are used, the portion adjacent to the threaded length should be relieved to eliminate the sharp stress raiser created by the last thread. Again, on shafts, good practice is to provide pads or portions of enlarged diameter for seating gears or wheels. In no case should changes in section be located so as to weaken the section.

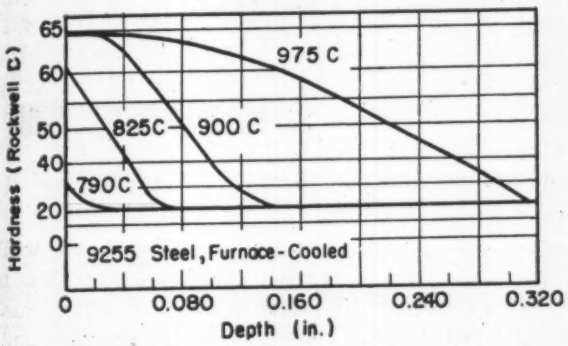
Selection of Materials

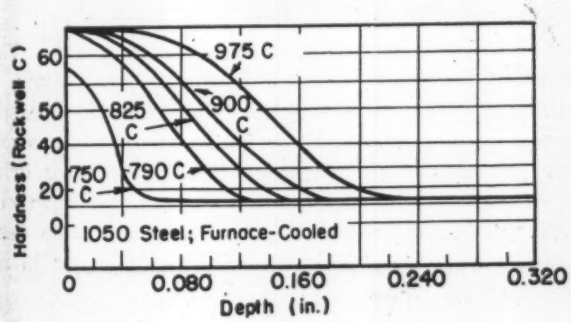
The process of selecting the right steel for any part is so closely concerned with design considerations for satisfying service conditions that the major portion of this problem has been covered. As a rule, more than one steel can be found to satisfy the necessary design requirements. Final selection, therefore, will involve consideration of price, processability, availability, and so on. A generalized grouping of some typical standard steels, listed from top down according to cost, starting with the lowest, is given in TABLE 3. Those in any one group may be used interchangeably, in varying degrees, of course, depending upon the specific design requirements.

Specifications. It is seldom good practice to specify both a hardness range and a physical property range. Often, one may be incompatible with the other. The best method is to select one or the other to provide maximum flexibility and economy.

Carburizing Steels. For carburizing processes, steels with 0.25 per cent carbon, maximum, are generally







preferred. The best steels are said to be the nickel-molybdenum alloys. In order of desirability, carburizing steels might be listed as follows:

AISI 4615 or 4620
C-1118
C-1117
C-1022 or C-1016
C-1020 or C-1015
C-1120 or C-1115

Normalizing. Certain steels are designed primarily for normalizing treatment; i.e., chromium-molybdenum, manganese-vanadium, manganese chromium-vanadium, and chromium - molybdenum - vanadium steels. At 0.15 to 0.25-carbon level the steels are suitable for carburizing, at 0.25 to 0.35-carbon for quenching and drawing, and at 0.35 to 0.50-carbon for normalizing and drawing. Only a normalizing and drawing treatment is employed for obtaining desired strength in larger sections such as massive turbine rotors, ship shafting, and big forgings far too large for regular quenching to martensite. The triple-alloy chromium-nickel-manganese NE steels provide normalized properties markedly superior to those of plain-carbon or manganese steels normalized in small sizes. To develop optimum toughness in the molybdenum 8600, 8700 and 9800 steels, the normalizing treatment must be followed by tempering.

Surface hardening. Selection of a particular steel for surface hardening requires some consideration of the distortion permissible as well as depth desirable. Martin and Van Note have shown that various steels respond with differing depth of hardness and hardening at different temperatures,* *Fig.* 13. Here it can be seen that specifications may vary widely depending upon conditions.

Specification of Tolerances

Accuracy of heat-treated parts has been covered to a considerable extent in the preceding discussion. The major factor to be dealt with is distortion. This factor can be great; herringbone gears of 24⅛-inch diameter and 4-inch face width, for instance, showed a physical distortion of 0.030 to 0.050-inch when pack hardened conventionally, whereas only 0.010-inch was experienced when flame hardening and martempering were utilized. Cost was reduced from $4.80 per gear to $0.90 per gear during the process of selecting a treatment to overcome excessive scrap and finish machining. Rings for ball races, 80½ inches OD and 68½ inches ID, have been flame hardened with a maximum out-of-roundness of only 0.030-inch and out-of-flatness of 0.025-inch, even though complicated with holes, slots, gear teeth, etc. Rings 30 inches in diameter by ¼-inch in section show less than 0.010-inch distortion, out-of-roundness or out-of-flatness. Generally, the lower the temperature at which treatment is accomplished, the lower the distortion, owing to less violent temperature and consequent structure changes.

Table 3—Standard AISI Similar Steels*
(according to cost, least expensive at top)

Group I	Group II	Group III	Group IV	Group V
C-1015 to 20	A-5120	C-1035 to 45	A-5140	A-4340
B-1112	A-8620	C-1137 to 41	A-4145	A-3250
C-1117	A-3115 to 20	A-1335	A-8642	A-2345
	A-4615 to 20		A-3140	
			A-4640	
			A-6145	

* Groups are not complete. Others may be added to suit particular requirements.

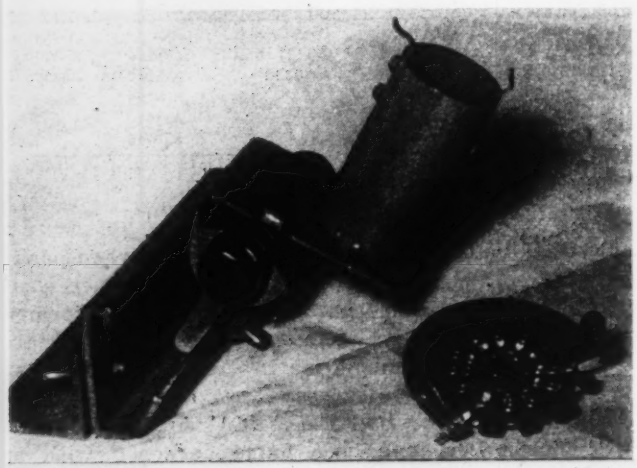
Case Hardening. As a rule, most case or surface hardening processes can be expected to produce a fairly accurate, uniform case. However, pack carburizing generally is found to produce a case which may vary, at a minimum, plus or minus 0.010-inch in thickness. Hence, this method is seldom specified for cases under 0.025-inch for this reason.

Grinding. Where extremely close tolerances are imperative, it is normally necessary to resort to a finish grinding operation to attain them. However, in many instances, selection of the proper treatments will make possible the elimination of any finishing after treating. Where grinding is utilized, the actual amount of material to allow depends upon the anticipated distortion which must be checked in actual practice.

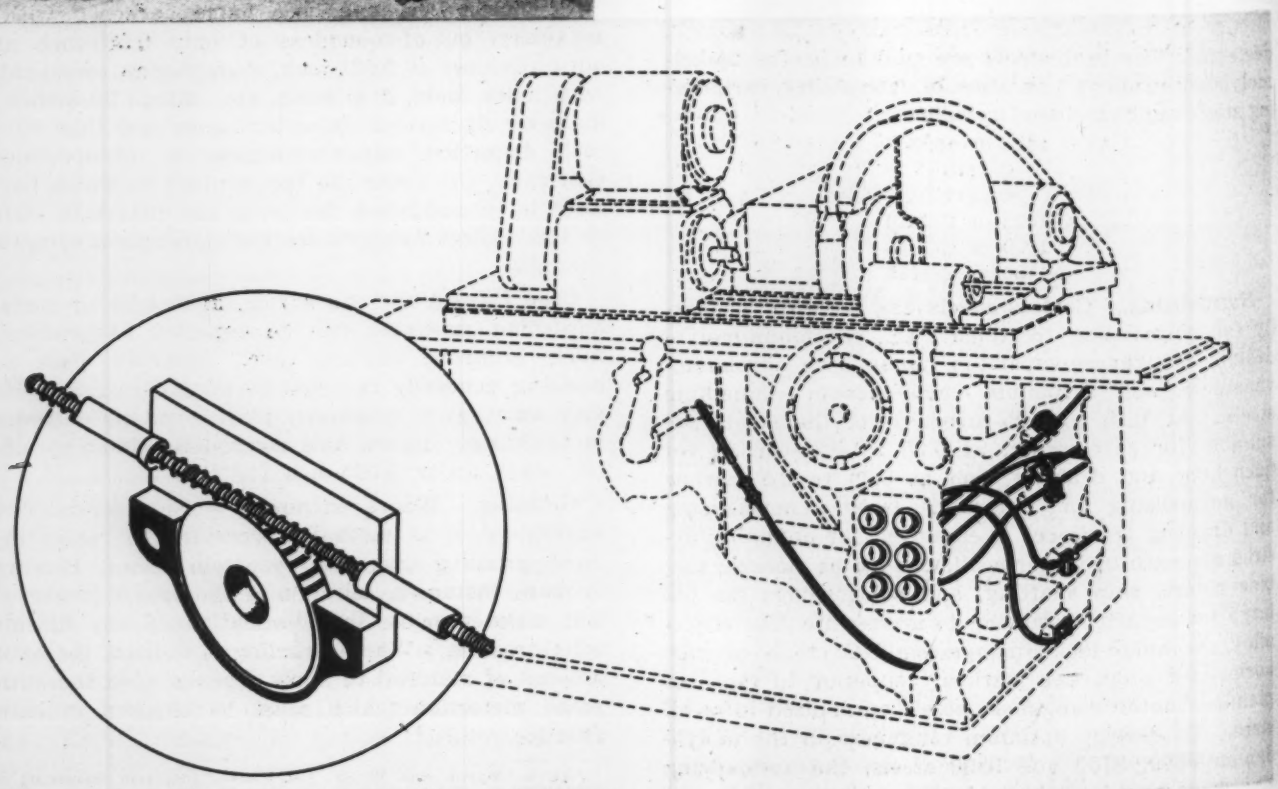
* D. L. Martin and W. G. Van Note—"Induction Hardening and Austenitizing Characteristics of Several Medium-Carbon Steels", *Transactions ASM*, Vol. 36, 1946.

SCANNING the Field For

Flexible worm drives suitable for positioning controls or for transferring light loads on a conveyor are illustrated below. Employed in the controls of a grinder, the drive positions worm gears in the control system. Installation is facilitated inasmuch as the flexible shafting requires no alignment between control and position stations. Limited displacement of either station, such as on a moving head, would not interfere with operation of the worm. The insert sketch shows the worm and gear arrangement employed in the control box and on the machine units.

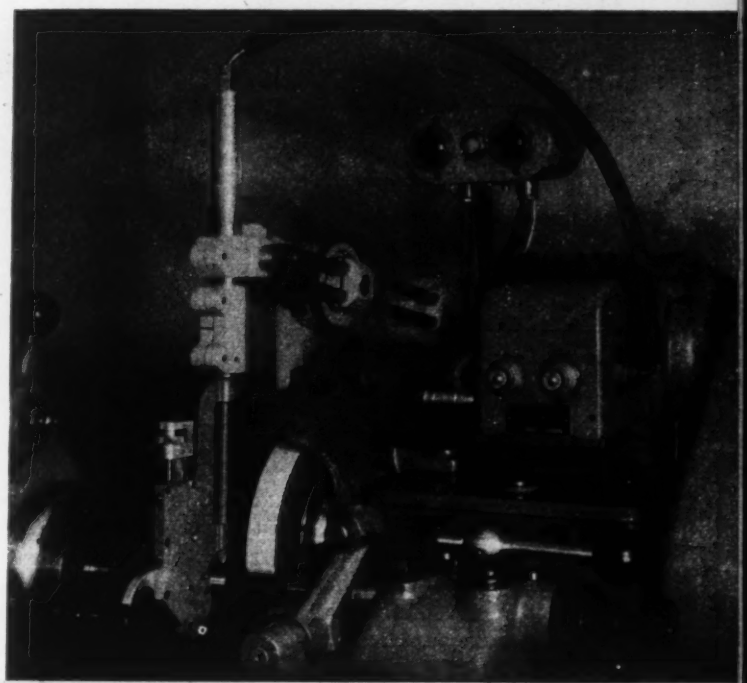


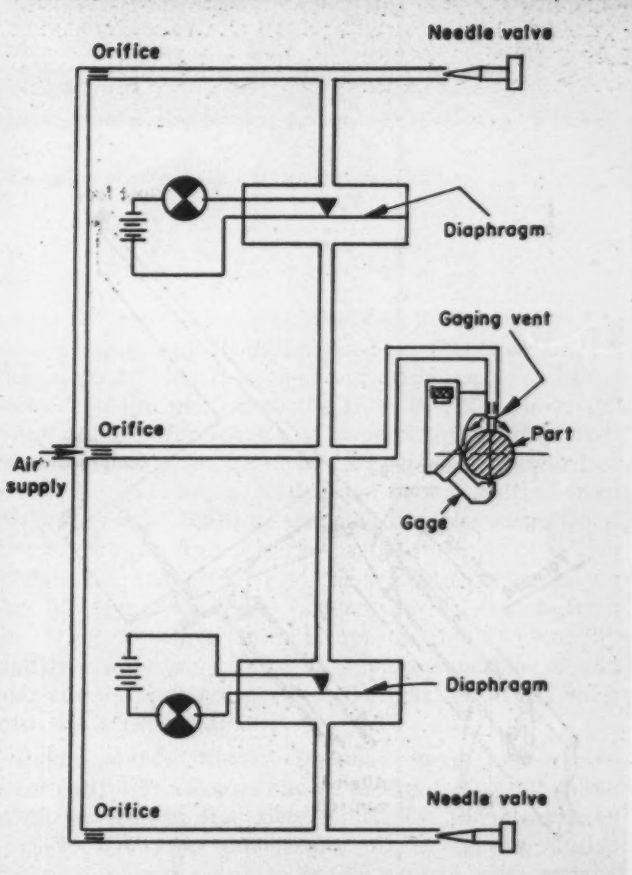
Shown at left is a section of a carrier rail and flexible worm used in processing radio parts. The worm on the shaft engages the fixture, conveying it to the next station. Curves in the carrier are easily followed by the shafting. Being a one-way conveyor, it requires no return path and little power for driving. Developed by Teleflex Inc. as an outgrowth of its remote control shafting, the unit has also been utilized successfully as an overhead conveyor in infrared drying ovens.

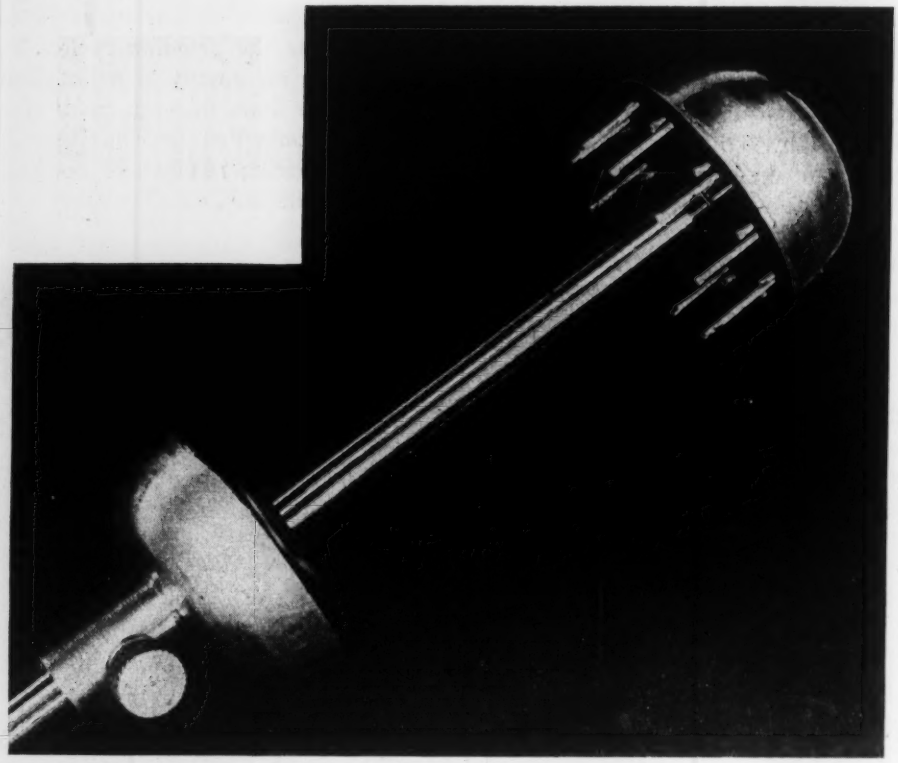


Automatic gaging with air jets increases the accuracy and production of grinders by controlling the machine cycle as illustrated at right or by sorting production from a centerless grinder as shown below. In the former, the control indicates by lights whether the part is oversize, near size or on size. Sensitive to one micron (0.000040-inch), the control retracts the grinding wheel and stops the machine when the part is ground to size. In the latter machine the gage sorts, through gates and chutes, into three bins those parts which are on size from those which are oversize and from those that are undersize.

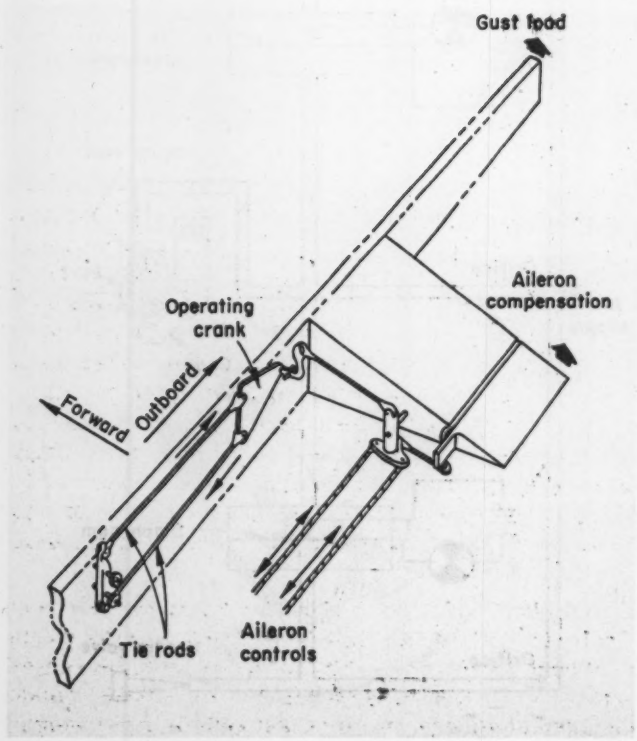
Operation of the gage, designed by Ateliers de Normandie, Paris, France, is based on the flow of air through orifices at critical speeds. Principal features of the circuit are shown in the sketch, right below. Part to be measured is placed in the jaw-shaped gage having two carbide tips and a contact finger which restricts the gaging vent proportionally to the diameter of the part. This vent is located at the tail end of an air supply tube having a calibrated orifice at its head end. Two other tubes in parallel with this tube similarly have orifices in their head ends and needle valves in their tail ends. Connected between the tubes are two diaphragms, each controlling switch contacts. The needle valves may be adjusted to operate corresponding diaphragm switches at different gage-measurement diameters. For instance, when the first switch closes the wheel feed may stop and spark out until the second switch operates to back the wheel and complete the grinding cycle. To insure accurate gaging, the air supply is maintained at 60 psi or higher. The air flows through small slits directly on the part to be controlled, preventing clogging of the orifices and insuring removal of coolant, grease, abrasive, etc., from the part.







Thermocouple probes, above, arranged to produce direct-current voltage bearing a direct relationship to the velocity of an airstream, provide accurate sensing units for anemometers and flowmeters. The thermopile consists of a series of thermojunctions with alternate junctions fastened to copper mounting studs with high thermal conductivity. Heated by an alternating current, the pile is cooled by the air flow. A thermal difference results between successive junctions, which induces d-c voltage proportional to the temperature difference between the alternate hot and cold junctions, the cold junctions being fastened to the mounting studs and maintained at ambient temperature. The thermopile adjusts itself to ambient temperature changes, but is subject to erroneous indications during the adjustment period. Where sensitive and continuous compensation is desired, an additional pile is connected in series with the indicating instrument employed for measuring the d-c voltage. This second pile is similar in construction to the heated sensing element but is not heated and is arranged to have opposite polarity. Transient effects of rapid temperature change thus cancel entirely. Designed by the Hastings Instrument Co. Inc., this heated thermopile unit has advantages over the usual hot-wire types in that the indicating or recording unit measures a d-c voltage of appreciable magnitude instead of small changes in resistance, eliminating errors introduced by lead resistance.



Gust alleviator, left, shown attached to a vertical section of a wing spar, is the result of more than two years research by the Air Force and the Douglas Aircraft Co. It shows promise of permitting the design of lighter aircraft for the same job as heavier predecessors. It also may provide commercial air travelers with faster and more comfortable transportation. The mechanism automatically adjusts the plane's ailerons, independent of the aileron control, whenever the plane encounters gusts or strong air disturbances which cause it to rise or fall suddenly. If the action of these gusts on the plane is relieved, the structure may be lightened.

When an upward gust meets the plane, the wings bend upward. This deflection is converted through the mechanical linkage of the gust alleviator to movement of the aileron in proportion to the deflection. The gust load, shown applied to the outboard end of the wing, causes upward deflection of the wing. Tie rods fixed to the inboard end of the spar rotate the operating crank about its pivot in proportion to the deflection. Outboard end of this crank moves downward and, through two additional cranks and connecting links, pivots the aileron upward. Aileron controls are pivoted on a common crank in the alleviator mechanism so that the gust compensation is independent of the control setting.

Designing Aircraft Main Spar Frames

. . . requires judicious selection of materials and fabrication method

By Melvin Stone *Design Specialist, Douglas Aircraft Co., Long Beach, Calif.*

EACH of the many component parts in a modern airplane has an important function to perform and is a design consideration in itself. Design, fabrication and materials selection for one of the most vital elements of the basic structure of a large cargo plane, the fuselage spar frame, will be discussed in this article.

In the C-124A low-wing, all-metal transport plane, *Fig.* 1, the wing is attached directly to the fuselage. Two main spar beams in the wing go through the fuselage and connect to the two main spar frames in the fuselage. In a low-wing airplane the floor beams between spar beams run longitudinally and, consequently, any loads imposed on the floor in this region go directly into the wing structure. For cargo stowed on the portion of the floor directly above the wing, acceleration loads are transmitted directly from the wing to the cargo. For cargo stowed forward or aft of the main spars, loads must be transmitted from the wing to the fuselage skin and into the cargo floor. The main spar frames serve as the medium by which loads are transmitted from the wing to the cargo via the fuselage structure. Loads may be traced from the wing to other components of the airplane by similar reasoning. Thus, the main function of the spar frames is to redistribute the reaction of the wing into the fuselage shell.

Fig. 1—Above—Two main spar frames and cargo floor are shown superimposed on this view of the C-124A transport plane. Spar frames distribute wing load to the fuselage shell and thence to the cargo

PRELIMINARY DESIGN: The main spar frames have practically flat sides as shown in *Fig.* 2. Overall shape of these frames was determined by the clearances needed to enclose almost any of the trucks, tanks, and road equipment up to 64,000 pounds gross weight

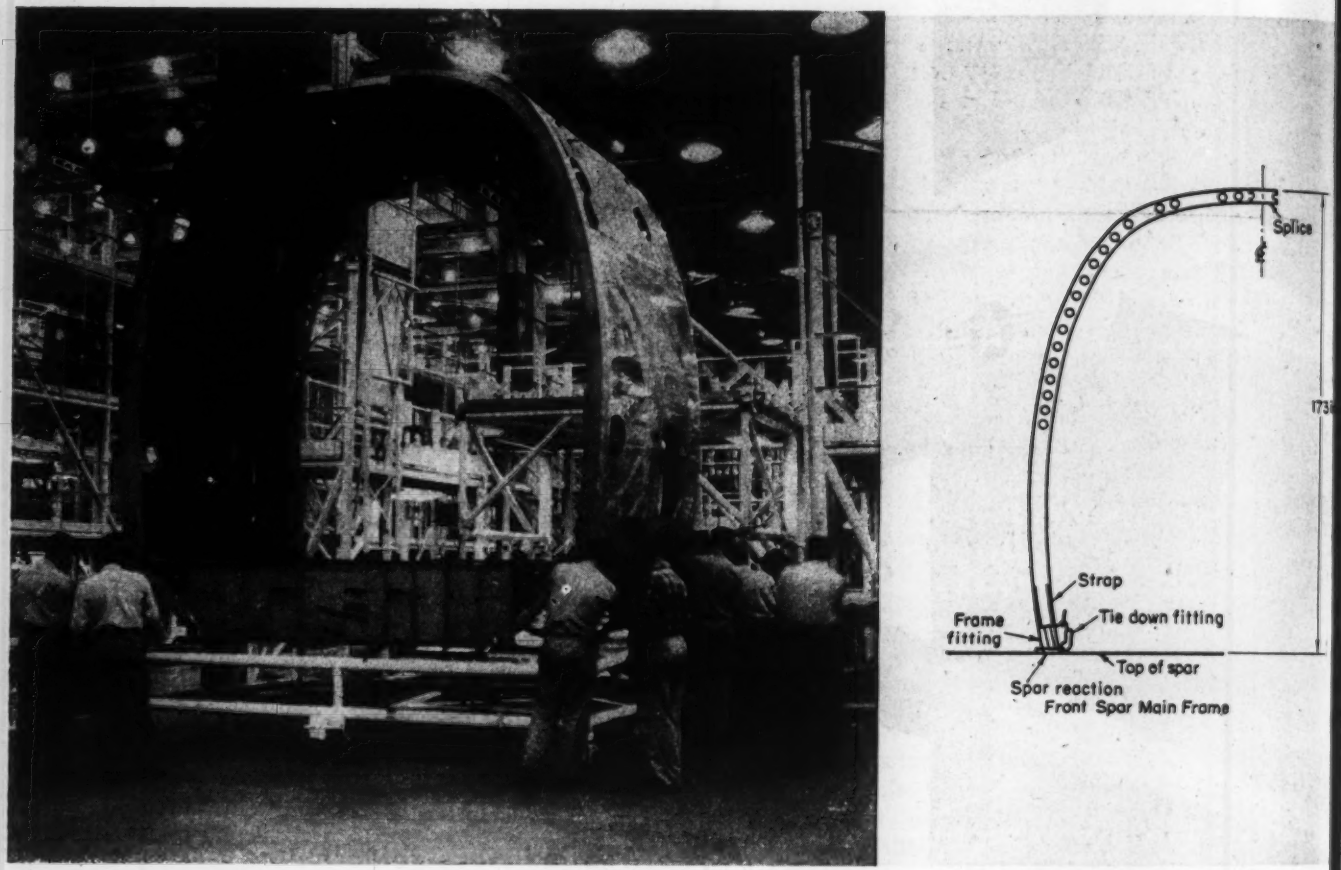


Fig. 2—Partially assembled view shows design of main spar frames. Inset sketch gives details of front spar main frame

necessary for use in combat, *Fig.* 2. In the preliminary design stages, several types of frame were considered: (1) the two-hinged arch, *Fig.* 3*a*; (2) the three-hinged arch, *Fig.* 3*b*; and (3) a rigid frame, shown in *Fig.* 3*c*.

The first two frame types develop zero bending moments at the hinged points, but maximum moments at other points in the frame. Therefore, the bending moment curves vary from maximum to minimum or zero over very short lengths. It is difficult to produce a tapered section that will fit this severe bending moment pattern. The three-hinged arch further complicates matters by having an extra joint which requires heavy end fittings and introduces even more severe changes in sections for an efficient design.

The third, rigid frame type shown has a number of inflection points (zero moments) but the magnitude of bending moment does not vary too much. Therefore, in this case the cross-sectional area of the frame can be better utilized. Another important consideration was that the deflection of the frame at the wing spar connection was required to be kept to a minimum. The wing inherently tends to bend at the frame connection, placing a large load at this connection. If the frame end is pinned the rest of the fuselage will tend to take out this load. It was also necessary to place the material where the loads are naturally imposed. With these requirements, a rigid frame offered the best solution.

From the production standpoint a constant spar frame cross section would be best, because it could be stretch wrapped on a Hufford machine, eliminating special jigs and tools and resulting in a better production rate. Also, hand straightening operations could be kept to a minimum because constant pressure on the part during stretch-forming minimizes formation of buckles. A built up section consisting of plates riveted together was also considered, because it could be tapered according to the bending moment diagrams. This design was discarded because the riveting, handling problems and number of detail parts required would be uneconomical. Although both engineering and production agreed that a constant section would be more favorable, an investigation as to cost and weight was necessary to justify the final choice.

Bending Moment Diagrams Essential

At this stage it was necessary to obtain bending moment diagrams for analysis of the critical frame conditions.

For irregular frames many special methods of analysis have been developed and published. Solution to the statically indeterminate structure was made for a symmetrical spar reaction. The frame is so constructed that the wing spar becomes the lower closing section of the frame. The critical frame loadings are symmetrical and the stiffness of the wing spar is large compared to the frame stiffness.

Therefore, the frame top center line was chosen as the origin of co-ordinates. The frame was then divided into many small increments of length over which the bending moment and moment of inertia was assumed constant. Only one-half of the frame was considered because of symmetry. Then, the evaluation of the deflection terms by means of tabular computations was accomplished. The energy equations used were:

$$\frac{\partial E}{\partial M_o} = \Sigma M_o \frac{ds}{I} + \Sigma H_o \frac{yds}{I} + \Sigma M_q \frac{ds}{I} = E\theta$$

$$\frac{\partial E}{\partial H_o} = \Sigma M_o \frac{yds}{I} + \Sigma H_o \frac{x^2 ds}{I} + \Sigma M_q \frac{yds}{I} = 0$$

Terms in these equations are illustrated in *Fig.* 4. In addition, M_q is the static moment of the assumed shear flow distribution about the centerline of each element, and I is the moment of inertia of the section. The integration was extended from the frame top centerline to the attachment of the frame to the spar and only the energy of bending considered.

Constant Section Most Effective

In the C-124A spar frame, the moment of inertia of the fitting at the wing juncture was added to the moment of inertia of the frame. The bending moment diagram is shown in *Fig.* 5, plotted on the side of the frame that is in compression, as is customary. Where the bending moment is maximum, the combined moment of inertia of both frame and fitting was used. On other portions of the bending moment diagram, the magnitude of bending is fairly uniform although sometimes opposite in sign. Therefore, a constant section could be used very efficiently by taking advantage of the fitting attached directly to the frame. This particular fitting is unique in that it takes the wing reaction and tie-down loads, as well as resisting part of main spar bending.

From *Fig.* 5 it can be seen that the actual bending moments are slightly lower at the top of the frame than on the side above the fitting, but other loading conditions had to be considered. First two hoist rails are attached at the upper part of the spar frame. These rails are used as tracks for a traveling crane, *Fig.* 6. Reactions imposed on these rails dictate design of the upper portion of the spar frames. These loads are only imposed on the frames during ground operations, but are large enough to influence design of the upper portion of the frame.

Also, the aerodynamic suction loads or pressures on the fuselage in the vicinity of the wing are quite large. On a flat-sided fuselage, this imposes heavy loads on the intermediate frames between the main spar frames. Therefore, due to the stiffness of the spar frames some of the loads were redistributed by skin and stringers and intercostals from the lighter

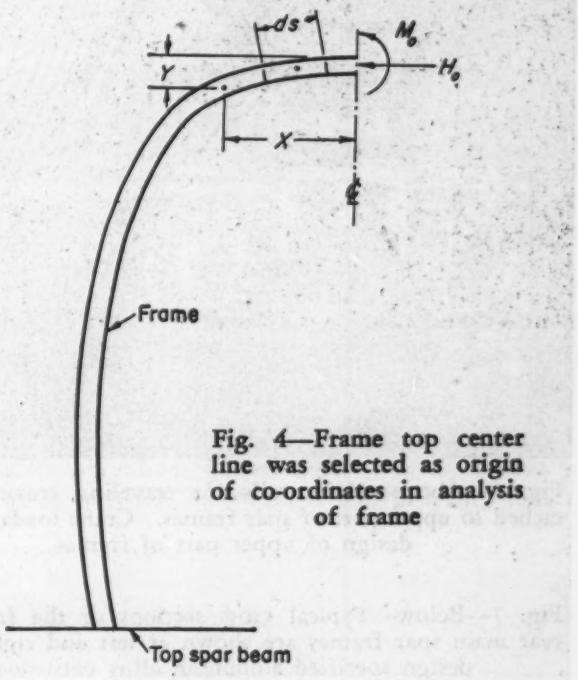


Fig. 4—Frame top center line was selected as origin of co-ordinates in analysis of frame

Fig. 3—Frame types considered include two-hinged arch, *a*, three-hinged arch, *b*, and rigid frame, *c*. Rigid frame type was finally selected

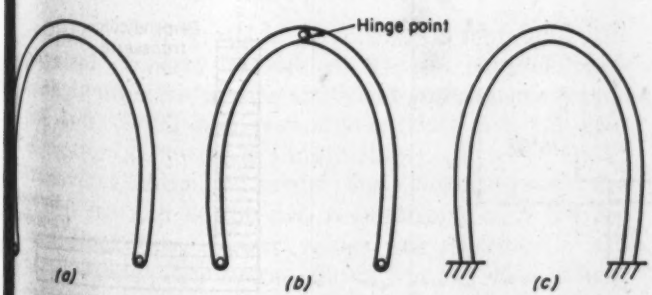
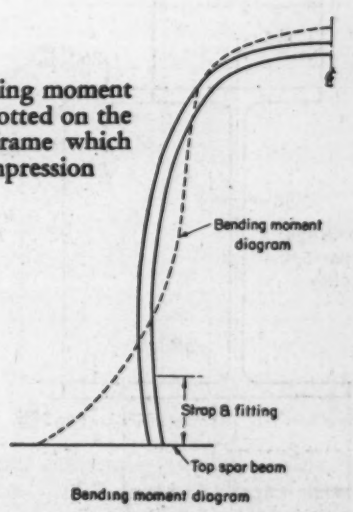


Fig. 5—Bending moment diagram is plotted on the side of the frame which is in compression



intermediate frames to the heavier main spar frames. This helped to keep the intermediate frames lighter. Finally, the clearances required for the handling and stowage of large cargo items precludes the use of bulkheads in the main cabin area. Consequently, the main spar frame must also serve as a stiffening section or element to cut down deflection of the fuselage.

It was finally decided to use a frame of constant section, because the entire extrusion shape could be utilized with a minimum amount of machining and with no weight reduction.

A number of preliminary cross sections of the actual frame were used in order to establish the correct dies.

MATERIAL SELECTION: Material to be used was given careful consideration. First to be considered was 14S alloy due to its high fatigue and good extruding qualities, but finally 75S aluminum alloy was chosen for its higher physical properties and relatively good fatigue and extrusion qualities. Additional information under the heading of 75ST material is contained later in this article.

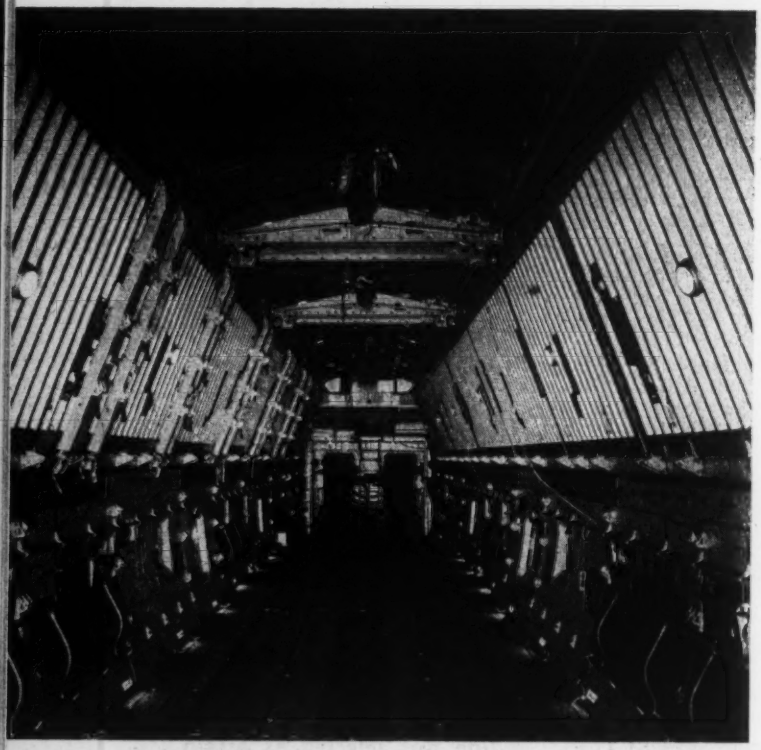


Fig. 6—Above—Hoist rails for traveling crane are attached to upper part of spar frames. Crane loads dictated design of upper part of frames

Stretched In Annealed Condition

Consideration was also given to the temper at which the 75S material would be stretched and straightened. If the material was stretched in the T-6 condition (heat treated and aged) the amount of stretch would have to be kept below 0.25 per cent elongation, so that the compressive yield stress of the material would not be reduced appreciably. Also, high pressures would be required to stretch the material in this condition. Of course by stretching in the T-6 condition, the number of operations would be kept to a minimum, except that it would be difficult to straighten the section after forming. Stretching in the S-O condition (annealed) would increase the number of heat treat operations and necessitate straightening after heat treat, but would insure a

Fig. 7—Below—Typical cross sections of the front and rear main spar frames are shown at left and right. Final design specified aluminum alloy extrusion

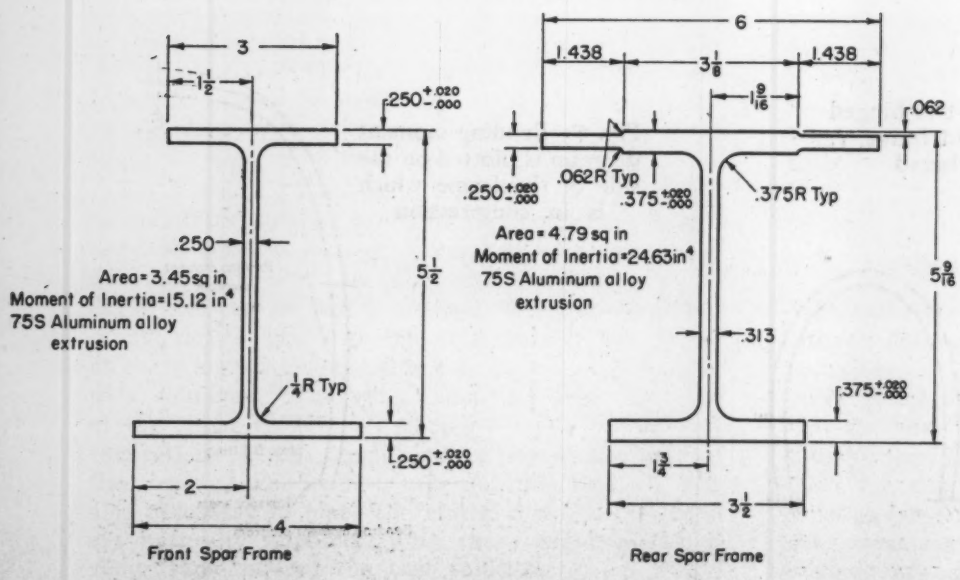
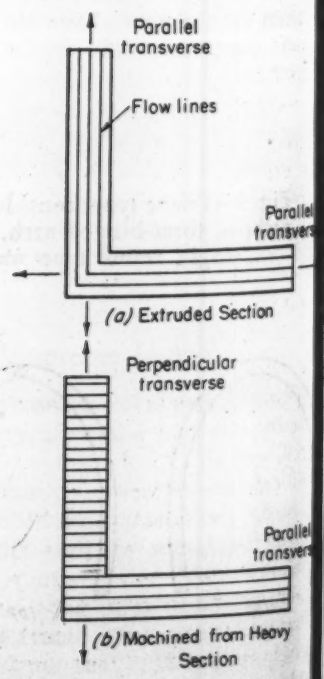


Fig. 8—Direction of grain i fluences physical properti Extruded sections have flo lines as at *a*, parts machin from heavy sections as at



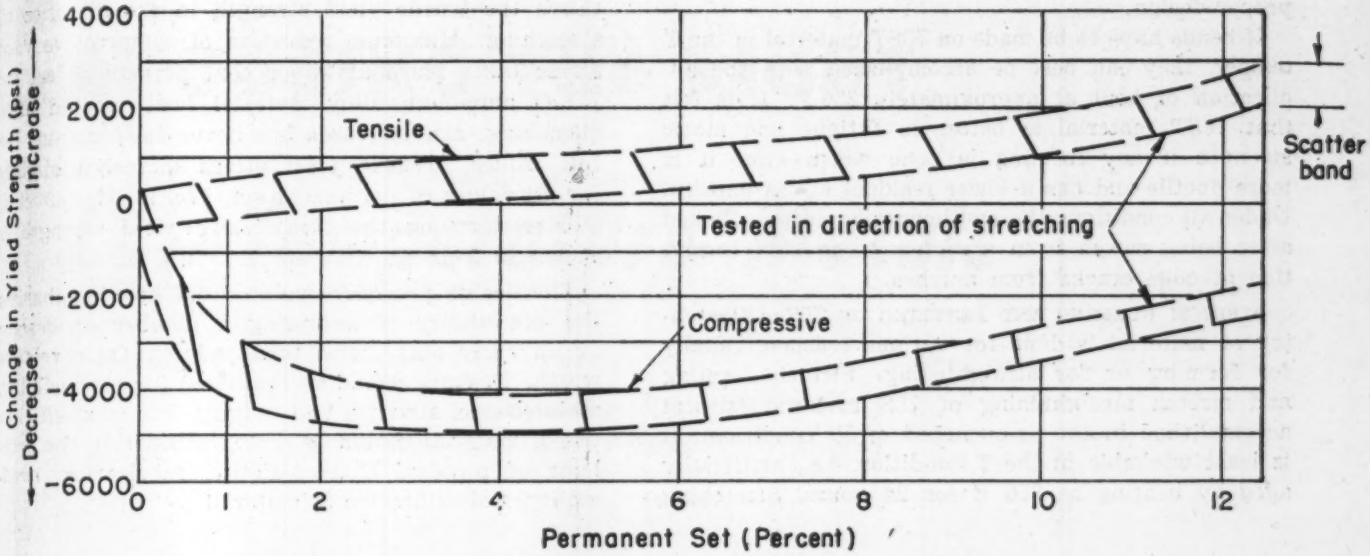


Fig. 9—"As-quenched" stretching of 75S-T increases yield stress slightly for all values of permanent set; compressive yield strength decreases up to about 4 per cent permanent set

better finished product. It would also allow the section to be stretched to a higher percentage of elongation. Therefore, in order not to impose too close a tolerance on stretching and straightening and to provide less chance of breakage, the S-O condition was chosen.

In considering the reduction of area due to stretching, it was felt that the stretch in the S-O condition would result in minimum reduction of area and better conformity to the outside contours. Reduction of area for a given length and material varies directly with the stress applied. The T-6 condition works to higher loads and stresses and deflects more than material in the S-O condition, which results in lower reduction in area for the latter.

Fig. 7 shows typical cross sections of the front and rear main spar frames that were finally designed for extrusion.

NOTES ON 75S MATERIAL: Parts of relatively thin cross section that are cut from the center of heavy sections, or parts machined from large billets, have reduced static and fatigue strength transversely. This has to be taken into consideration during the design of a particular part, *Fig.* 8*a*.

Grain Direction Critical

Direction of grain is important in obtaining the physical property allowables. Typical parallel longitudinal ultimate tensile and yield stresses are 88,400 psi and 79,200 psi, respectively, with 9.5 per cent elongation (showing grain direction). Typical parallel transverse ultimate tensile and yield stresses are 77,000 psi and 68,200 psi, respectively, with 6.1 per cent elongation. Lower values are obtained in the perpendicular transverse direction, *Fig.* 8*b*. These values are so much lower that it is good practice to make sure the stresses are kept low in the perpendicular transverse direction. It should be noted that the values cited here are all typical and above the minimum.

The question of notch sensitivity and fatigue is highly controversial. Most authorities feel that elongation is a measure more of quality than fatigue, and is not too good a parameter by which to judge the fatigue strength of material. On the other hand, if 75ST parts are designed properly to avoid sharp notches, they will fall in the scatter band along with all other aluminum material. If a ⅛-in. radius is necessary for 14ST material, it will probably take a

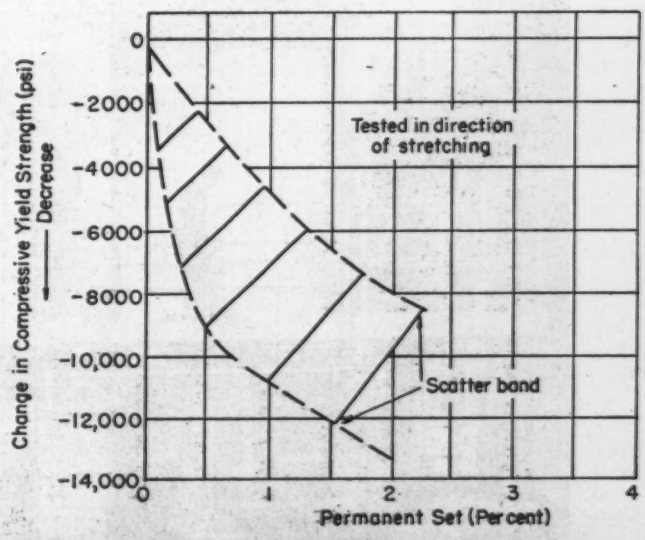


Fig. 10—When artificially aged by heating at 250 F for 24 hours, 75S-T material shows decrease in compressive yield strength

3/16-in. radius for 75ST aluminum alloy material for proper design.

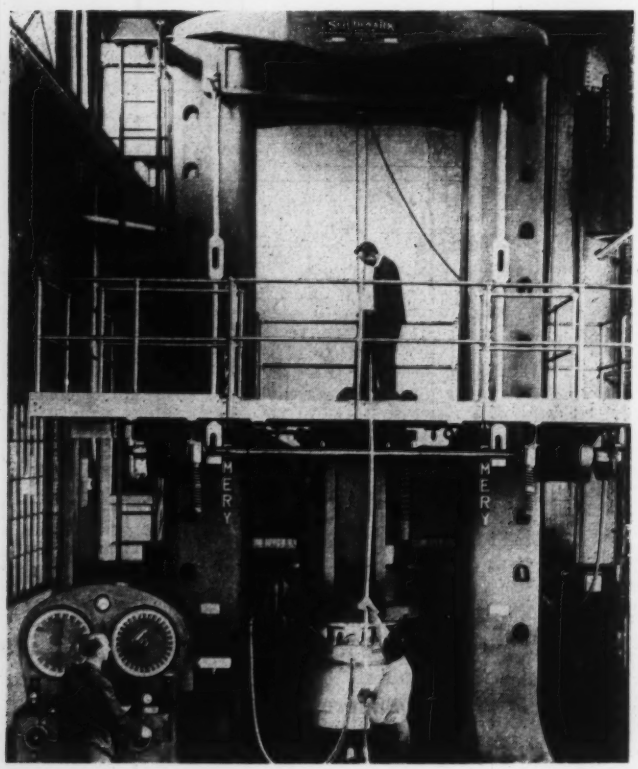
If bends have to be made on 75ST material in the T temper, they can best be accomplished with the application of heat at approximately 250 F. It is felt that 75ST material is better in fatigue and static strength if any forming is done warm since it is more ductile and has a lower residual stress pattern. Under all conditions the specimens should be polished after being sawed from a section to prevent formation of edge cracks from notches.

STRETCH FORMING AND LEVELING OF 75S: Stretching of material is done for various reasons, usually for forming or for straightening. Stretch forming and stretch straightening of 75S material is best accomplished in the as-quenched or W condition. It is least workable in the T condition, i.e., artificially aged by heating at 250 F for 24 hours. Stretching after quenching lowers the compressive yield and raises the tensile yield strength in the direction of stretching. Maximum reduction of compressive yield stress takes place at 2 per cent permanent set for 75S-O aluminum alloy material heat treated after quenching, and increases but never fully attains the full values. Tensile yield stress increases slightly for all values of permanent set, *Fig.* 9. The effect of T stretching on the compressive yield strength is shown in *Fig.* 10.

The design procedure pointed out here emphasizes the desirability of analyzing a number of designs at an early stage, and then judging their relative worth. Designs should be evaluated for producibility, maintenance, strength and weight. The most efficient use of material should be made, considering the problems of physical characteristics, fabrication, availability, and utilization of material.

Testing Machine Aids Research

IN THE development of production processes for the manufacture of aluminum and magnesium parts, the precision metal work that has been provided for by one of the largest and most powerful universal testing machines in America has proved to be of unusual value. For 10 years research engineers of Aluminum Company of America have been determining optimum conditions for extruding, forming and forging these metals and their alloys with this machine. Unlike most testing machines, this 3,000,000-pound tester has been in almost continuous operation in process development with only occasional use for tension and compression tests of these materials, or for tests of parts or structures made of them. One of the most striking differences between it and a standard testing machine of equal capacity is the maximum at which the load-applying head can be operated under full load. This was increased from a conventional 2 to 3 inches per minute to 36 inches per minute. Second major change was to provide an opening through the center of the sensitive crosshead and the Emery hydraulic, load-weighing cell on the crosshead. This provides for egress of extruded metal when the machine is used for the development of extrusion procedures for the various alloys or to suit the varying requirements imposed by different features of design.



The machine was speeded up by the use of a 300-hp motor and hydraulic pump capable of delivering 275 gallons of oil per minute. This is 15 times more power than would normally be provided in a testing machine of this capacity.

Extrusion process experimentation is of three types —direct, indirect, and impact. Two extrusion cylinders of unique design, weighing two tons each, are used for the first two methods. One is designed for operating temperatures up to 1000 F and the other for 700 F. These cylinders have a bore of 4 inches and an outside diameter of 32 inches. The walls are built up in two or three layers. In the higher pressure cylinder the outer layers exert enough external pressure on the inside layer to build up a compression load of 110,000 psi when the cylinder is not under pressure. At full extrusion pressure this becomes a tensile stress of 150,000 psi.

Impact extrusion on a hydraulic press is unconventional but is being done in the laboratory. In forging studies, various features of forging design and die design are studied in connection with variations in forging pressure, temperatures, ram speed, die lubrication, alloys, and other variables.

CHOOSING THE RIGHT

Low-Temperature Metals

By John R. Watt
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PRESENT demand for safe low-temperature metals is needlessly consuming expensive alloys and helping to deplete America's slender stockpile of alloy ingredients. Actually, scarce materials are not necessary in *all* low-temperature applications. Carefully selected ordinary metals plus proper design are usually adequate. Where these fail, consideration of low-alloy and low-nickel steels is justified.

The need for cold-resistant metals is two-fold. Military men know that tanks, aircraft and foot soldiers alike may someday face −79 F (the record for Canada) or even −94 F (Siberia's recorded low). In industry, processing equipment dewaxes lubricants below −70 F, gage blocks are stabilized below −100 F, butyl rubber is processed at −140 F, and oxygen is extracted from liquid air at −300 F.

At such temperatures, all metals are not safe, and selection must be made carefully. Specifically, low temperatures increase some strengths of metals and decrease others. Tensile and compressive strengths, elastic limit and modulus, fatigue strength, and hardness are increased in all metals. Tensile strength alone gains from one to three per cent for each 10 F temperature drop.

The "safe" metals are those whose toughness, ductility, and impact resistance also rise. In *Fig.* 1, aluminum, copper, nickel, and lead show such gains as temperatures drop; thus these metals are safe at all

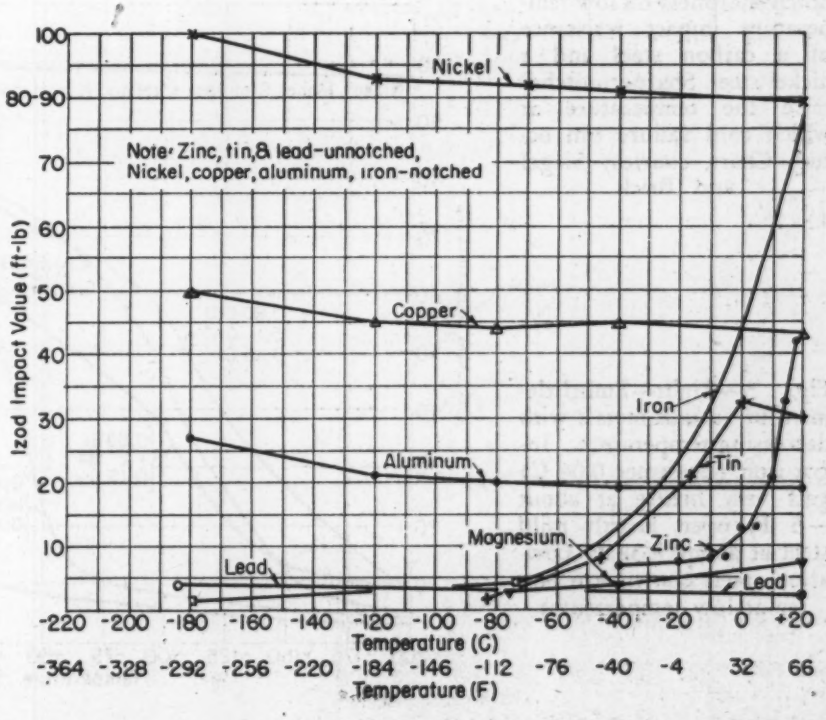


Fig. 1—Impact strength of pure annealed metals at low temperature with the exception that both zinc and magnesium are slightly alloyed. The safer metals for low-temperature work are nickel, copper, aluminum and lead

low temperatures. Their alloys are also safe; aluminum alloys 61S-T, 24S-T, and 75S-T have been tested down to −423 F. Additionally, alloys 2S, 3S, 17S-T, 18S-T, 25S-T, 52S, and 195T have been tested with similar success.

Among copper's alloys, aluminum bronze is erratic but tough to −423 F. Almost all copper alloys (including brasses with 38 per cent zinc) retain low-temperature impact strength. Magnesium is almost as safe; at −76 F it retains half its original shock resistance. Magnesium alloys M1, AZ61, A10, AZ63, and FS-1 show decline in subzero toughness, but enough remains for many applications.

Nickel and its alloys, Monel, H-Monel, K-Monel, Inconel, etc., are the toughest of all; their low temperature behavior is excellent.

The "dangerous" metals are those which become brittle with increased cold. *Fig.* 1 shows the poor impact resistance of pure iron, zinc, and tin as the mercury falls. Consequently, wrought and ingot iron, zinc and tin are dangerous in dynamic low-temperature service. For static service they remain safe; miles of wrought iron brine piping and thousands of zinc die castings are exposed to such temperatures and seldom fail. Tin alloys are used largely in bearings and food handling items; their temperature failures are rare. However, high-tin solders like 95-5 are questionable for low-temperature impact service.

DYNAMICS OF LOW-TEMPERATURE EMBRITTLEMENT: Metals like iron, steel, zinc and tin are termed "subject to low temperature embrittlement" or simply "cold sensitive." Similarly, the temperature at which impact strength falls to 50 per cent of normal is termed the "transition temperature" or "shock limit temperature". Actually four embrittling factors interact to create low temperature brittleness; (1) temperature, (2) velocity of impact, (3) presence of notches or stress raisers, and (4) thickness of the metal. Of these, *temperature* is most obvious. Impact tests upon temperature-sensitive metals reveal recognizable transition temperatures near the onset of brittle failure. *Fig.* 1 shows this near −4 F for pure (i.e., ingot and wrought) iron, between −20 and −30 F for tin, and between 10 and 0 F for zinc. These are purely relative, however, being influenced up and down by the other embrittling agents.

The *velocity of impact* is important; the higher the striking velocity, the higher the temperature at which

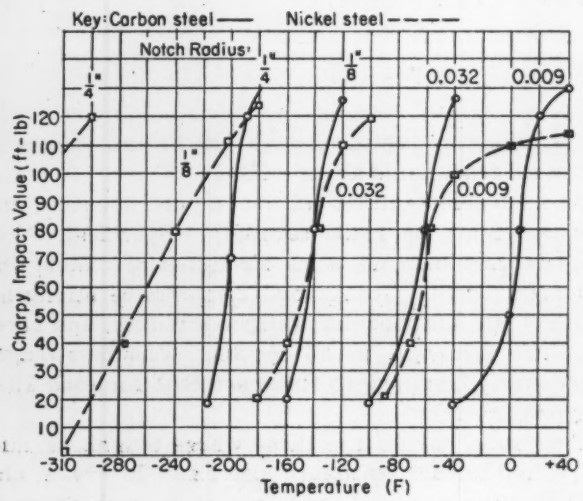


Fig. 2—Above—Effect of notch sharpness on low-temperature impact resistance of a carbon steel and a nickel steel. Sharper notches raise the temperature at which cold failure can occur—Chart, courtesy Siegel and Brick

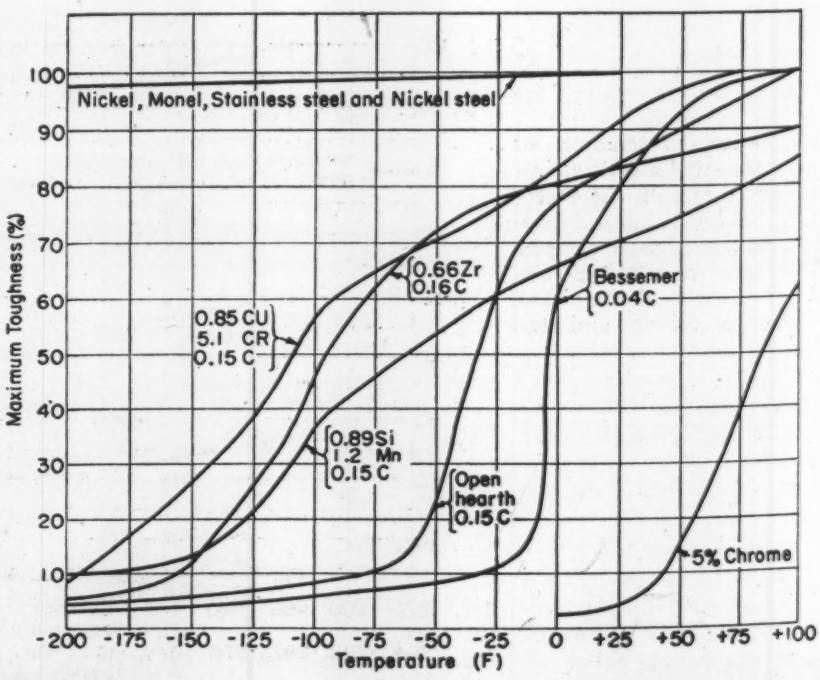


Fig. 3—Right—Embrittlement of various metals with decreasing temperature. Ingot iron (Bessemer 0.04 C) gets very brittle at about −5 F, open hearth mild steel at about −32 F. Low-alloy steels shown are better at low temperatures

brittle failure can occur. Increased impact velocity is equivalent to reduced ambient temperature or raised transition temperature. Thus, given sufficient impact velocity, even tough metals may have brittle failure at ordinary temperatures.

The presence of *notch stress-raisers* in the metal is similar. As shown in *Fig.* 2, the sharper the apex of a notch, the higher the temperature at which failure is possible. A member with a notch of 0.009-inch apex radius has a Charpy impact value of 50 ft-lb at 0 F while a similar member with ⅛-inch notch radius has the same value at −147 F.

This notch effect was chiefly responsible for failures occurring in all-welded Liberty ships, the early models of which had square corners in hatches and companionways. Failures occurred in near freezing weather and often without known causative impact. The steel plates tore in typical brittle fracture, often without parting the welds. Substitution of rounded corners in deck openings largely prevented further ship damage.

Small Notches Initiate Failure

To initiate low-temperature failure, notches need not be large; discontinuities in the metal, slag within a weld, machined recesses with sharp corners, or indentations from a letter-die or center-punch may suffice. Un-notched members have a simple uniform stress flow, but presence of a notch creates local triaxial stresses which augment the original load. The notch also hinders the deformation needed to distribute stresses evenly throughout the metal, so the load further concentrates at the apex of the notch, stressing that area excessively. Thus, even in lightly loaded members, one zone is already highly stressed and ill-prepared to absorb shocks. *Fig.* 2 shows the effect of temperature upon the notch sensitivity of a steel: at 40 F a notched member will absorb 130 ft-lb of impact; at −40 F, only 19 ft-lb. Clearly, notches must be avoided in low temperature shock items.

The fourth embrittling agent is the *size or thickness* of the member. Large thick members appear weaker in impact than equivalent thin ones, and impact tests with notched specimens of various widths indicate that large parts become brittle at higher temperatures. There are several explanations. First, large members create greater transverse stresses about any notch, hence increasing local stress concentration. Second, thick members suffer higher stresses than thin ones from equal flexure. Third, thick wrought members receive fewer benefits of mill rolling, the grain may be coarser and ingot porosity less completely removed. In heat treatment, large pieces also suffer from slower or less uniform cooling rates. In consequence of these tendencies, designers should use thinner, more flexible members.

COLD SENSITIVITY IN CAST IRON AND STEEL: *Cast and Malleable Iron.* The low impact strength of gray cast iron eliminates it from most shock applications at any temperature; at −300 F its toughness is 25 to 30 per cent lower yet. However, its static uses are undiminished and should not be overlooked. Malleable cast iron's natural toughness is similarly reduced by cold, but if moderately loaded it can be safely used.

Low-carbon steel. Mild structural steel fortunately has a lower transition temperature than wrought or ingot iron. *Fig.* 3 shows the embrittlement of ingot iron (labelled "Bessemer 0.04 C") around −5 F, and that of open hearth 0.15 per cent C mild steel about −32 F. Actually, much ordinary mild steel is used at even lower temperatures for light shock duty. Below −50 F it remains safe for static service.

Medium- and high-carbon steel. Any carbon content above about 0.15 per cent seems detrimental to low temperature toughness. In *Fig.* 4, the cold sensitivity of the three aluminum-killed fine-grained steels varies directly with carbon content. High carbon steels are the most temperature sensitive of all.

CHOOSING STEELS FOR LOW-TEMPERATURE SERVICE: If all carbon steels are temperature sensitive, how

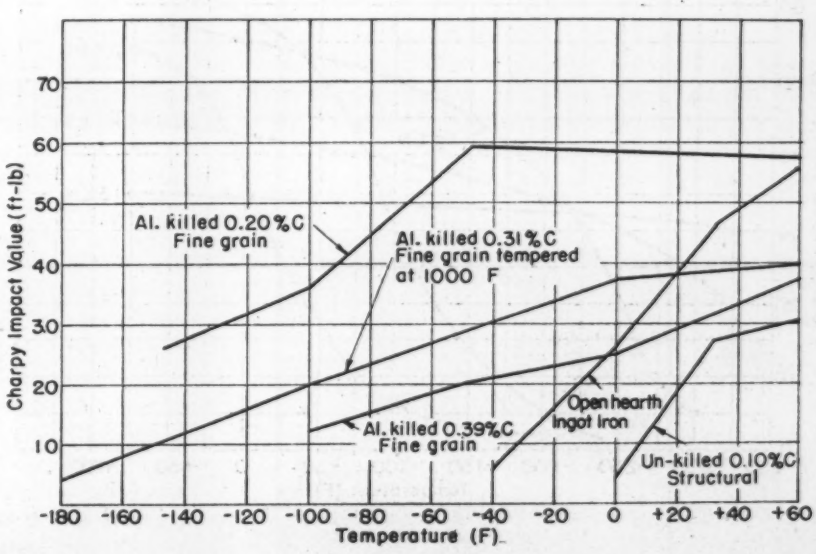


Fig. 4—Effect of carbon content, purity and grain size on low-temperature impact resistance. Cold sensitivity varies directly with carbon content — Chart, courtesy R. Franks

then can they be used? The first answer is obvious; where no impacts occur, steels may be used as though for room temperature. If safe at 70 F, they are safe below, for cold enhances their static properties.

However, where dynamic loads and shocks are probable, the steels must be carefully chosen. Several tips to aid the designer follow:

1. Use a pure steel. Inclusions of sulfides, oxides, etc., form tiny notches in the metal and raise the transition temperature. Hence, for low-temperature impact applications, designers should specify open hearth or electric furnace aluminum-killed steel. These are subzero tougher than semikilled, which are better than common unkilled and rimmed steels.

Pure Steel Required

The purity problem prohibits use of Bessemer or converter steel. *Fig.* 4 shows an unkilled 0.10 per cent C Bessemer structural steel whose transition temperature is about 16 F. Thus, designers should avoid mass-produced fittings, nuts, bolts, fastenings, etc., made of Bessemer free-cutting or screw stock like the SAE 1100 series. About 5 per cent of American steel is Bessemer made; it appears also in small lap and butt-welded pipe, in tin plate and galvanized sheet, in reinforcing bars, and in wire.

2. Specify fine-grained steels. Aluminum from the killing process greatly reduces grain size and raises subzero toughness. The open hearth 0.15 per cent C steel of *Fig.* 3 has a shock limit temperature of −32 F compared to −140 F for the aluminum-killed fine-grain, 0.20 per cent C steel of *Fig.* 4. Additions of vanadium molybdenum, titanium, or zirconium also refine the grain.

Small members may be given "grain refining" heat treatments, being heated to a temperature of known small grain size and quickly cooled. Conversely, any burning, prolonged heating or slow cooling in a manufacturing process causes grain growth even in fine-grained stock. Thus, castings, weldments and forgings are often given grain refining treatments before use.

3. Use hardened and tempered steels where possible. If medium or high-carbon steels must be used for low-temperature impact service, the designer should specify that they be hardened and tempered. The cold-toughness of mild steels can be similarly boosted.

Annealed Steels Are Sensitive

Most steels are delivered in their annealed or normalized state where slow cooling often precipitates carbides which act like impurities. Hence, annealed and normalized steels are in their most temperature sensitive condition. They should be appropriately heated and quenched, then tempered to the properties desired. Tempering between 1000 and 1200 F gives the maximum cold-toughness.

4. Use alloy steels only where really needed. For most purposes, plain killed fine-grain carbon steels are adequate down to −50 F. Below that, especially where moderate notch effects or impacts are anticipated, low-alloy high-strength steels are justified. These are low-carbon fully-killed fine-grain stock plus small amounts of nickel, chromium, copper, silicon, molybdenum, zirconium, manganese, vanadium, etc., from selected alloy scrap. *Fig.* 3 shows the superiority of three such alloys over a mild steel of equal carbon content. When hardened and tempered, these

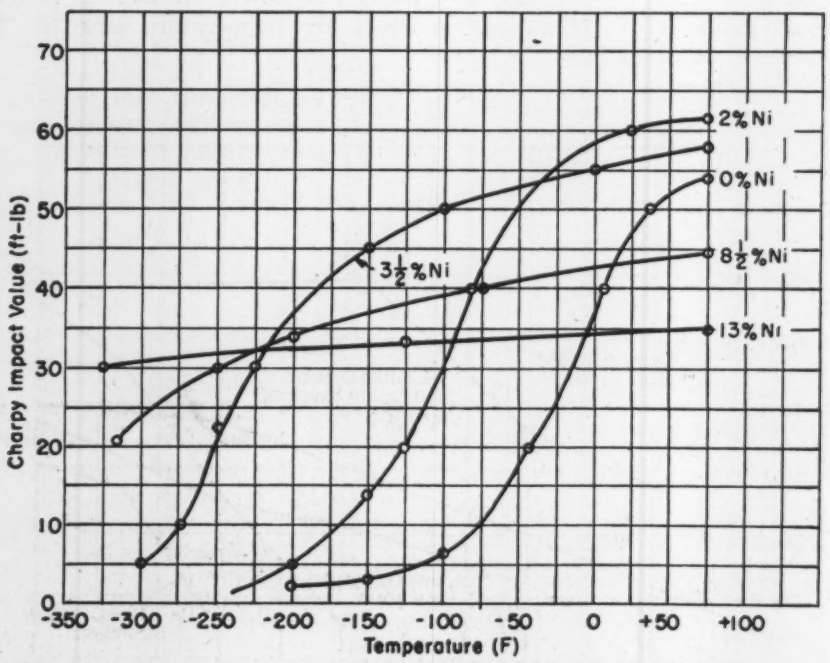


Fig. 5—Effect of nickel on the low-temperature impact resistance of normalized low-carbon steel. This series of low-nickel steels will fill many needs where fully-killed fine-grain carbon steels are inadequate—Chart, courtesy T. N. Armstrong

are safely used at temperatures down to −150 F.

Castings have less cold-toughness than wrought metals. If killed and heat treated, their use in low temperature shock service is limited to perhaps −50 F. Alloying, especially with nickel, is justified in this case.

For ultralow temperatures and very severe service, designers may specify low-nickel steels. *Fig.* 5 shows four grades: the 2 and 3½ per cent alloys are adequate to −100 and −150 F, respectively, for most uses; the 8½ and 13 per cent stocks will endure shock-loads and notch effects around −200 and −300 F, respectively. *Fig.* 2 shows how nickel content markedly reduces notch sensitivity.

Since most refrigerated equipment is shock-free, few applications need richer alloys than these. However, high-nickel alloys or Monel are available for unusually severe cases. Stainless steel (18-8) is satisfactory but incurs diversion of needless critical chromium.

EFFECT OF WELDING: The possibility of thermal and residual welding stresses imposes a warning—avoid overly rigid structures. The Liberty ship failures were abetted by severe prestressing from weld contraction. The rigidity of ship hulls is that of box-girders, and deformation-relief of these stresses was impossible. Many joints were critically stressed and required only falling temperatures to initiate fracture. Subsequent all-welded ships have strategic riveted seams as expansion joints to allow slippage to dissipate such loads.

Before 1948 the ASME Code for Unfired Pressure Vessels required special steels and impact tests for pressure vessels for service below −20 F. Several states follow this code today, although most have adopted the later one. The present version allows wider use of ordinary steels, so designers should use it where permitted.

Selecting Electrodes for Welding

Welded joints introduce several embrittling factors. Besides prestressing, they randomly heat-treat the surrounding metal, the degree of both varying with the number of passes of the electrode. Recent tests show that welding can incorporate notch sensitivity into otherwise excellent metal. Killed mild steel, which fractured at −80 F unwelded, had brittle impact failure as high as 10 F after welding with standard E-6010 electrodes of approximately equal ultimate strength. However, low nickel-molybdenum filler metal of 100,000 psi ultimate strength restored most of its toughness and greatly lowered the embrittlement range.

Thus, where subzero impacts are anticipated, electrodes of higher classification than the metal seem advisable. Below −50 F, low-nickel electrodes will greatly reduce the notch effects of the weld: 2 per cent nickel steels welded with AWS 8015 low-nickel electrode are used down to −75 F, and 3½ per cent nickel steel with the same electrode to −150 F. The higher nickel alloys are frequently welded with stainless electrodes. Heat treatment to refine the grain and relieve stresses should be considered after all welding.

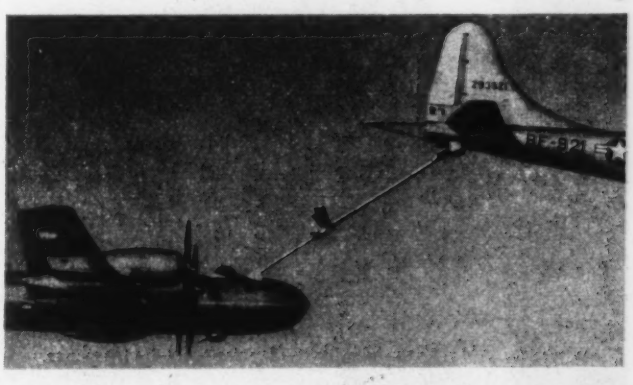
BIBLIOGRAPHY

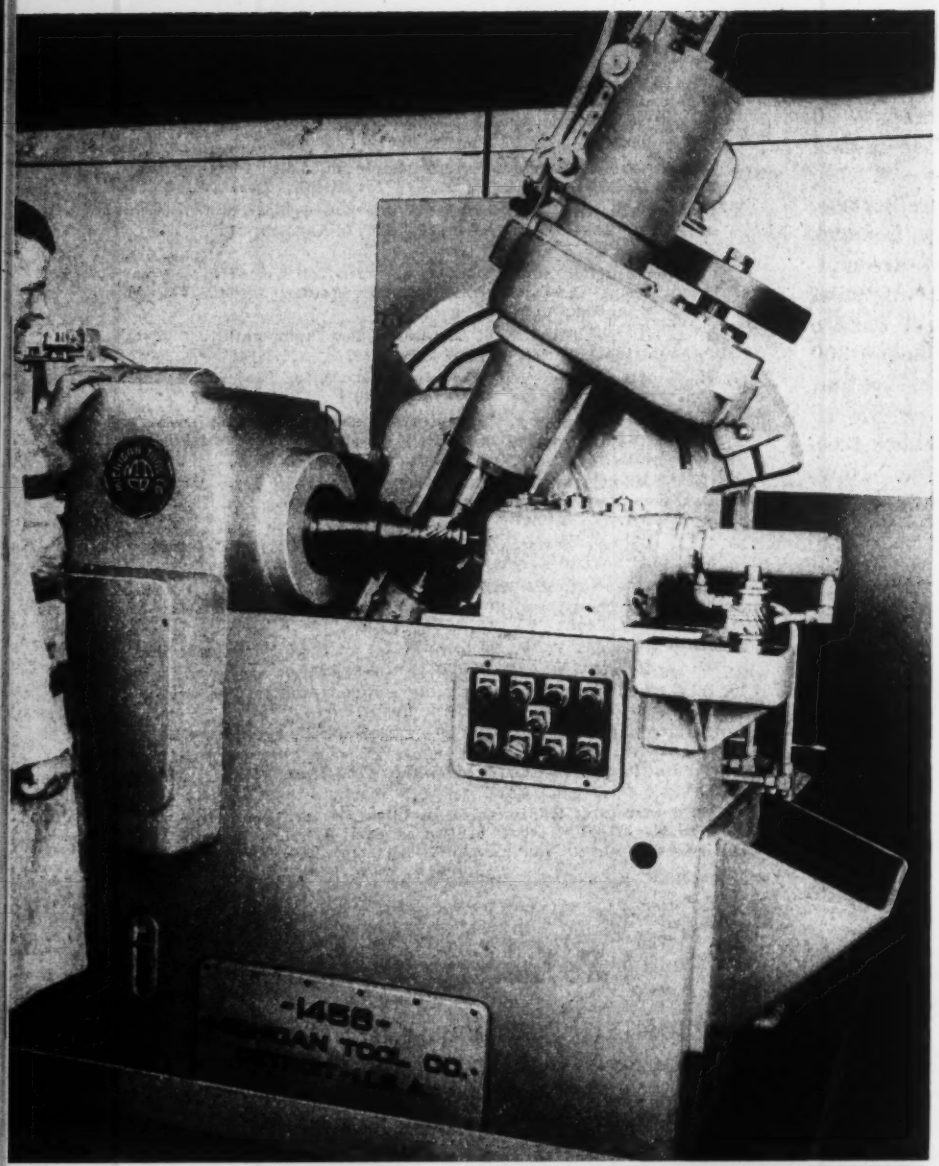
1. T. N. Armstrong—"On Low Temperature Properties of Metals," 1950 *Data Book*, Applications Volume, American Society of Refrigerating Engineers, New York.
2. T. N. Armstrong—"To Fortify Steel Against Cold," Inco, *Vol.* 19. No. 2, 1944.
3. Russell Franks—"Properties of Metals at Low Temperatures," *Metals Handbook*, American Society for Metals, Cleveland, O.
4. H. W. Gillett and F. T. McGuire—"The Low Temperature Behavior of Ferritic Steels," *Steel*, Vol. 119, No. 7, Aug. 12, 1946.
5. Otto Graff—"The Strength of Welded Joints at Low Temperatures and the Selection and Treatment of Steels for Welded Structures" (Translation), *Journal of the American Welding Society*, Vol. 26, No. 9, September 1947.
6. S. L. Hoyt—"The Use of Metals at Low Temperatures," *Metal Progress*, Vol. 58, No. 6, June 1949.
7. J. W. Jupponiatz—"Cast Ferrous Materials for Subzero Service," *Iron Age*, Vol. 163, No. 22, June 9, 1949.
8. F. H. Keating and E. V. Mathias—"The Use of Mild Steel for Service at SubZero Temperatures," *Proceedings of the Institute of Mechanical Engineers*, Vol. 163, No. WEP 55, 1950.
9. G. S. Mikhalapov—"Evaluation of Welded Ship Plate by Direct Explosion Testing," *Welding Research Supplement*, Vol. 16, No. 4, April 1951.
10. E. J. Ripling—"Subzero Properties of Metals Surveyed," *Iron Age*, Vol. 163, Nos. 16 and 17, October 19th and 26th, 1950.
11. L. Seigle and R. M. Brick—"The Mechanical Properties of Metals at Low Temperatures: A Survey," *Transactions of the American Society for Metals*, Vol. 40, 1948, Pg. 813.
12. C. E. Sims and F. W. Boulger—"Steel Castings for Subzero Use," *Metal Progress*, Vol. 51, No. 2, February 1947.
13. P. L. Teed—*Properties of Metallic Materials at Low Temperatures*, John Wiley and Sons, New York, 1950.
14. J. L. Zambrow and M. G. Fontana—"Mechanical Properties, Including Fatigue, of Aircraft Alloys at Very Low Temperatures," *Transactions of the American Society for Metals*, Vol. 41, 1949, pg. 480.
15. "The Structural Reinforcement of Liberty Ships," and "Design and Methods of Construction of Welded Steel Merchant Vessels," *The Welding Journal*, Vol. 23, No. 9, September, 1944.

Refueling in Flight

UNUSUAL anti-icers built for use on the new flying boom in-flight aircraft refueling system, developed by Boeing Airplane Co. for the U. S. Air Force, are rubber in which heating wires are imbedded. Made by the B. F. Goodrich Co., they will be installed on the control surfaces of the telescoping fueling pipe that is lowered from the tanker.

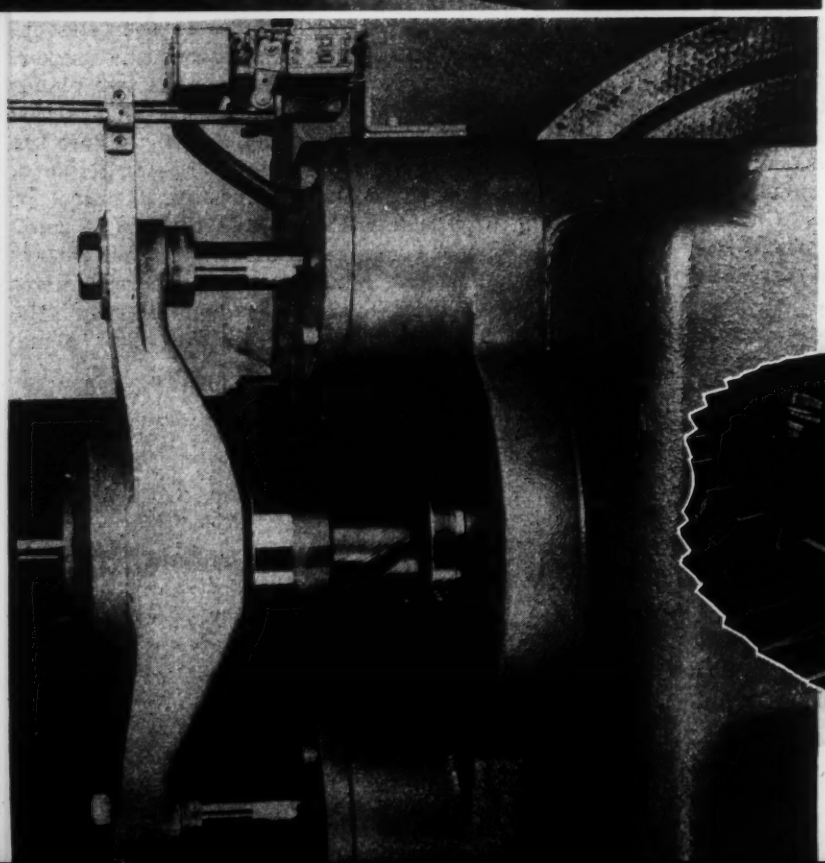
In using the new refueling method, the two planes fly in formation and the refueling boom, carried under the tail of the tanker plane, is inserted into the special socket in the nose of the plane being refueled. Fuel is then delivered under pressure. Control of the fueling tube is possible through the use of small V-shaped control surfaces which govern movements of the fueling boom. A crew man in the rear turret of the tanker plane operates controls to "fly" the fueling nozzle into the socket on the other plane.

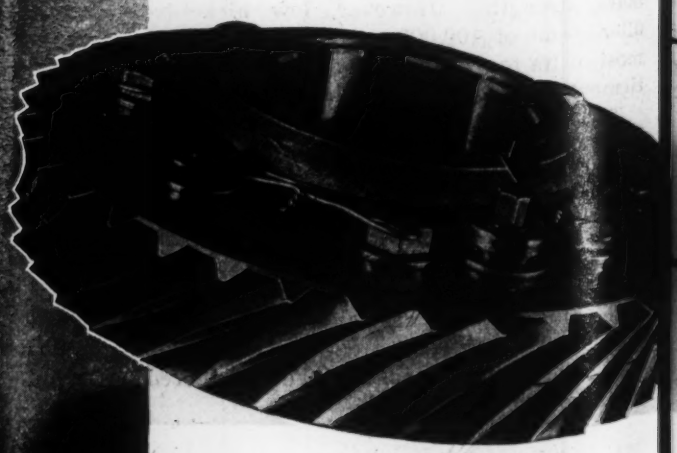




Hobber Cuts Ge

HIGH-PRODUCTION gear hobber for fast hob-generating of accurate gears and splines, made by Michigan Tool Co., is illustrated at the left. Relative travel of hob or work during the cut has been reduced by eliminating all but 1/16-inch of approach feed of the hob. This is made possible by two separate feeds in sequence, a plunge feed of the hob to correct depth followed by a traverse feed of the work across the hob. Feeds of ⅛-inch per revolution of the workpiece are handled by the machine. Lead errors are avoided by mounting the lead cam or guide directly on the work spindle, photograph at left, below, thus virtually eliminating torsional windup in the hob spindle drive. Cone-Drive double enveloping gearing is used for index and main drive gears.



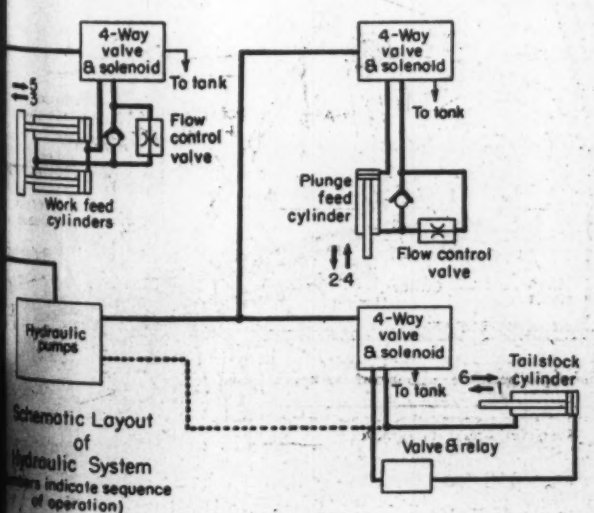


achining Time

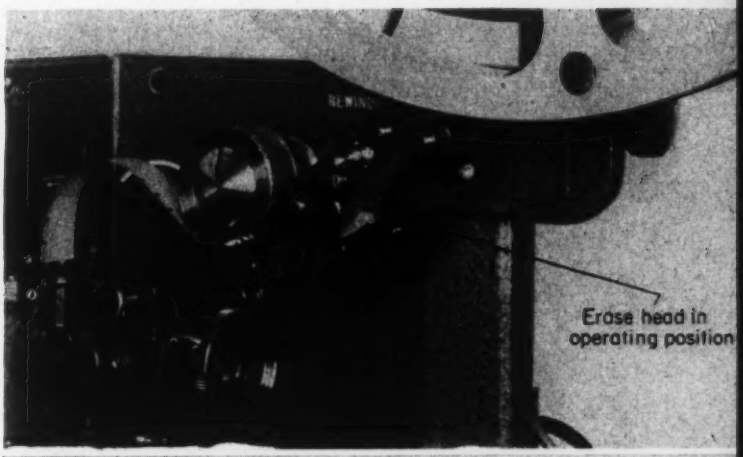
These gears, in closeup photograph below, are of split construction so that in the event of wear, the cam shown by the arrow in the photograph may be turned to remove backlash by a slight relative shift in the two gear halves.

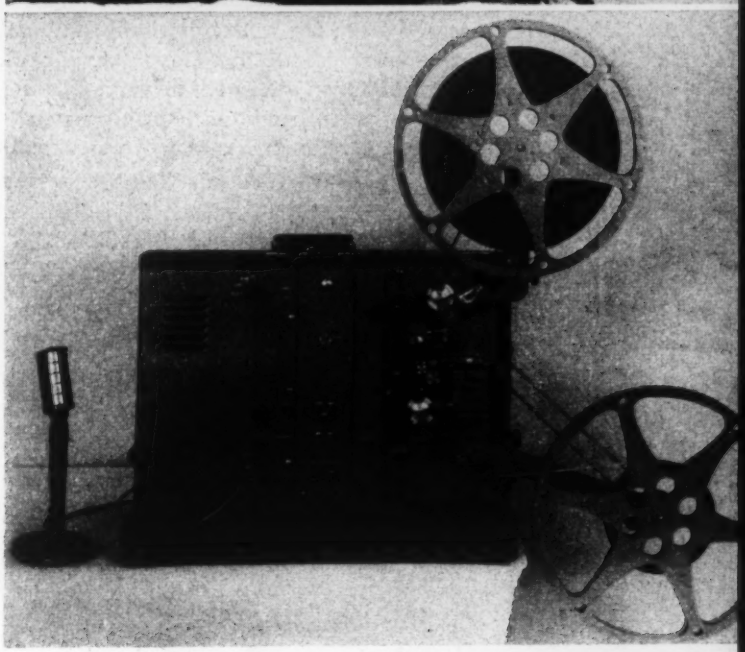
Rate of feed is adjusted by setting dials on two valves, one for the plunge-cut feed and one for the traverse feed, both these feed rates being infinitely variable. Either climb or conventional hobbing can be used. A diagrammatic layout of the hydraulic system of the hobber is shown below. The tailstock cylinder is used both for retracting and approach and to maintain constant pressure (300 pounds) on the work spindle. The plunge feed cylinder also rapidly retracts the hob spindle when the end of the cut is reached. Work spindle cylinders operate at 500 psi.

The hobber is designed to handle helical or spur gears or splines up to eight inches in diameter and 4¾-inch face width. It can turn out, for example, two 3⅛-inch diameter, 9 pitch, 2-inch total face width, 22-tooth helical gears to close tolerances in 58 seconds using high-speed steel hobs.



Schematic Layout of Hydraulic System (numbers indicate sequence of operation)





Projector Employs Magnetic Recording

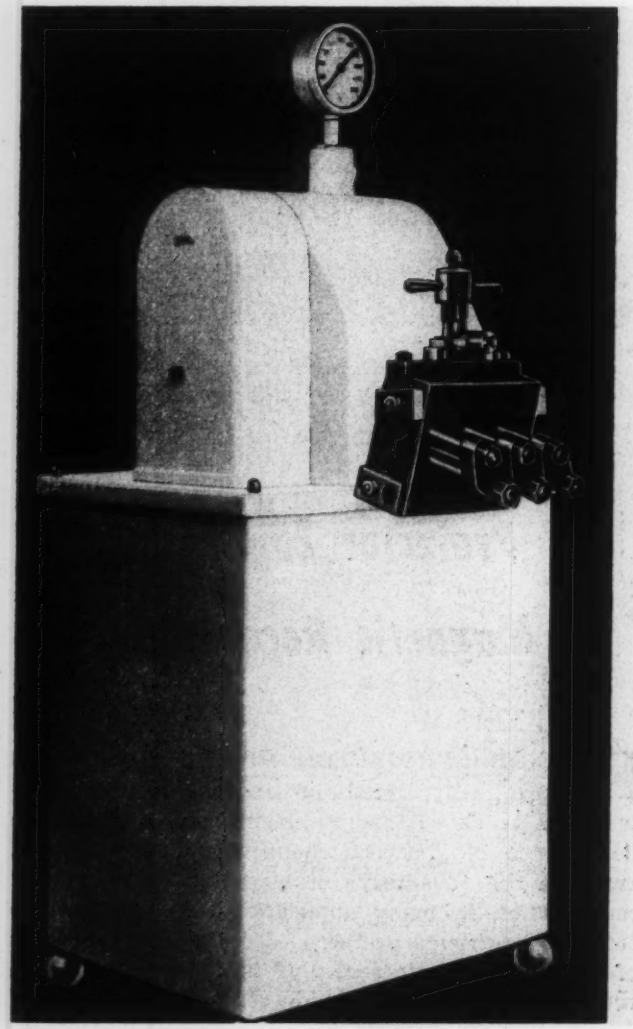
RECORDER-PROJECTOR which records sound magnetically directly on the edge of 16-mm picture film is shown above. Manufactured by Radio Corporation of America, the new equipment makes available the advantages of magnetic recording and reproduction in many applications where allowable costs are restricted by the need for a limited number of prints. Magnetic recording is done on a 0.1-inch wide stripe of magnetic oxide coated on the edge of

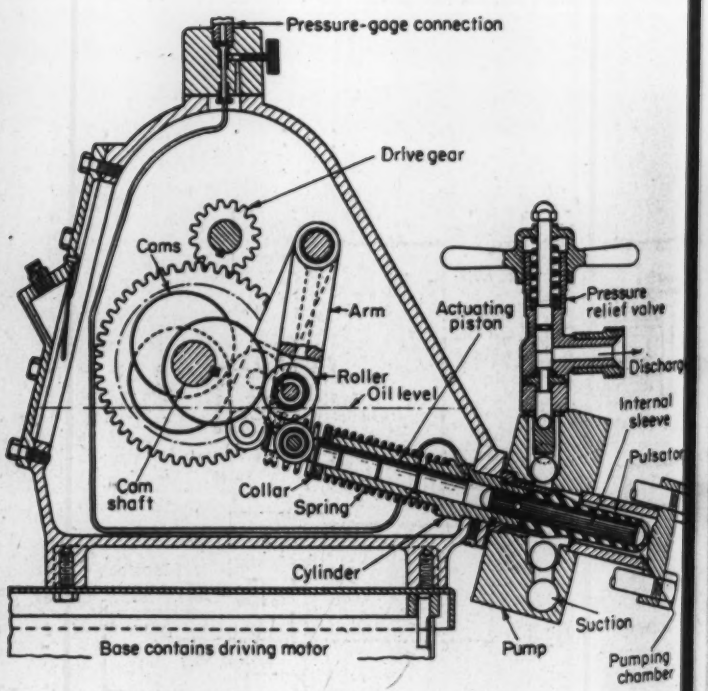
the film either before or after it has been exposed, even if the film already has an optical or photographic sound track. In addition to recording and reproducing magnetic sound, the "400" Magnetic Sound Projector can be used to reproduce optically recorded sound. An electronic erase head permits revisions or rerecording. Cost of recording a 400-foot reel of film with this equipment is estimated to be about one-third that of achieving comparable results photographically.

For magnetically recording or reproducing sound, a head or transducer is positioned with respect to the constant speed drum to contact the inside of the film loop as it is being pulled around the drum. One edge of the film projects beyond the rear edge of the drum for the magnetic recording or reproducing operation. For both recording and erasing the erase head (close-up photograph top of previous page) is pushed down into position for threading, the film being passed between the head and a nylon shoe under the head.

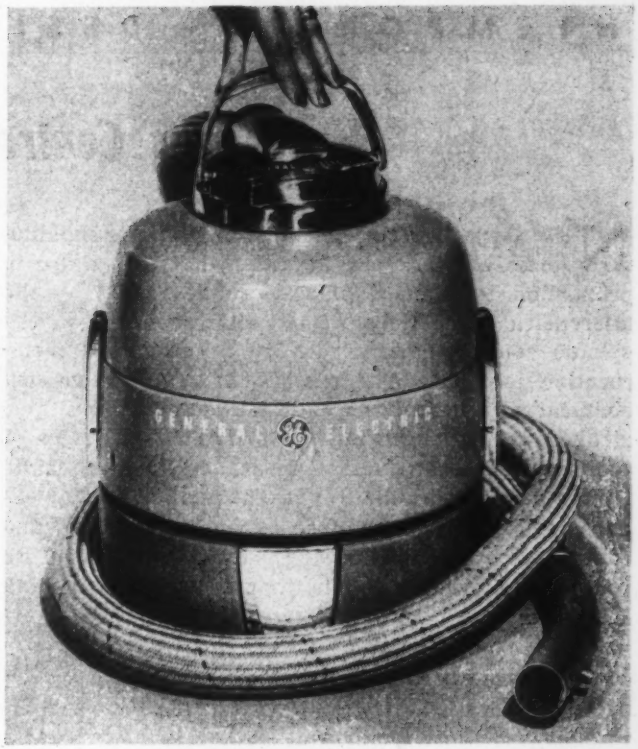
Homogenizer Pump Isolates Liquid

HIGH-PRESSURE, leak-proof, positive displacement hydraulic pump in the Scott & Williams Hydropulse homogenizer, below, isolates the material being processed from the pump mechanism, eliminating chances of contamination. The pump, drawing below, right, employs cams to drive actuating pistons which pump oil into synthetic rubber pulsators. On the suction stroke, the rubber pulsator collapses onto its internal metal sleeve, creating a suction which draws liquid into the pumping chamber. On the pumping stroke, the piston forces oil inside the pulsator, causing it to expand and fill the pumping chamber, thus forcing out the material being pumped into the discharge line. The homogenizer requires no packing or stuffing boxes, has no cylinders to seize or score, can run dry without damage, and is self-priming. The unit is built in capacities from ½ to 2½ gpm and for pressures to 3000 psi.





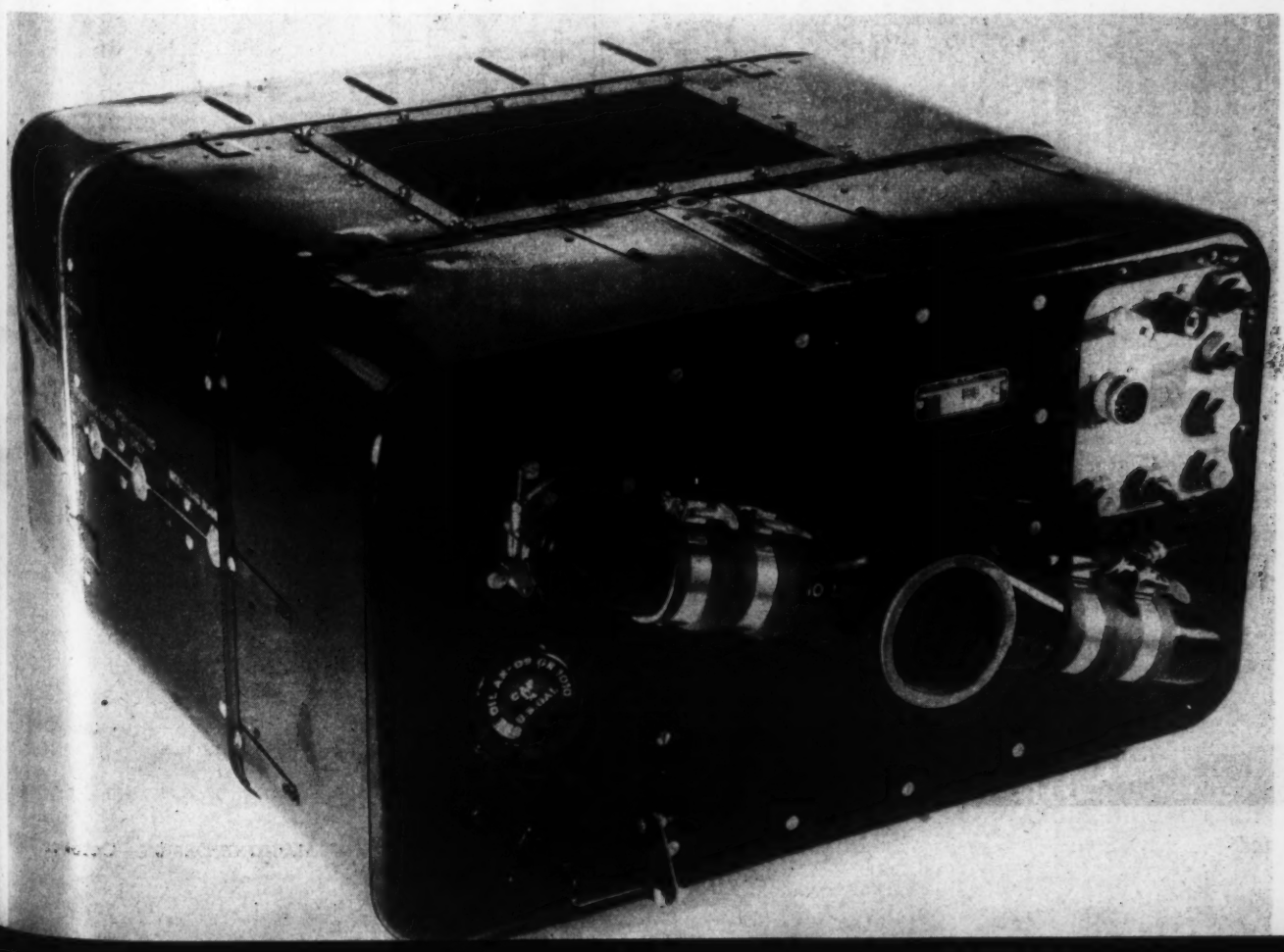
Swivel Top Increases Sweeper Range



VACUUM cleaner with swivel top, right, allows cleaning an entire average-sized room from one central point, extension tubes and hose which fit into the rotating cap giving a reach of over eight feet in any direction without moving the cleaner. Made by General Electric Co., the unit can be pulled along the floor while in operation. Other design features are a dirt storage capacity double that of conventional tank type cleaners, a disposable dirt bag and a diffused air exhaust system. Measuring 11 inches in diameter, standing 13½ inches high and weighing 17¾ pounds, the cleaner is finished in two-tone gray with chrome and polished aluminum trim.

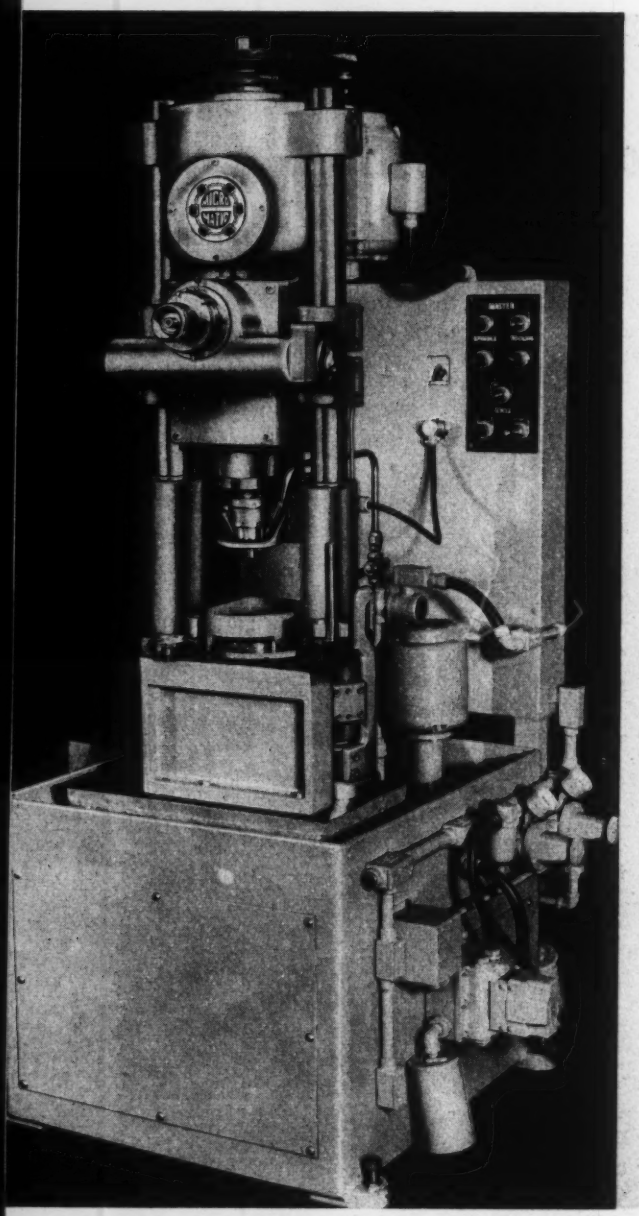
Small Turbine Powers Accessories

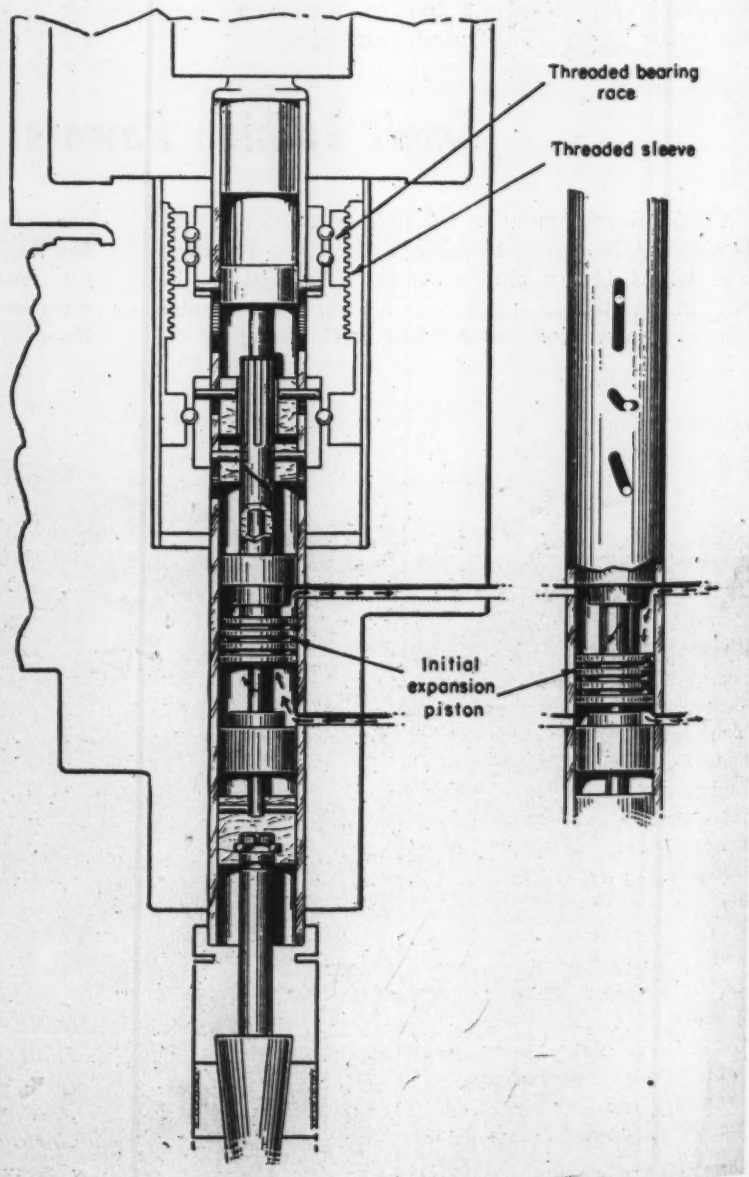
LATEST development in the field of small gas turbines, AiResearch Manufacturing Co.'s compressor model 43/44-5 is shown below. Designed for installation in turbine-propelled aircraft to furnish pneumatic power for self-starting and accessory operation, the complete turbine-compressor unit is about the size of a hand valise. Entirely enclosed and with all necessary controls, this integral-cooled model weighs only about 150 pounds, develops over 100 air horsepower.



Honer Has Controlled Tool Expansion

NEW type honing machine, below, for holding precise tclerances in bores that are short in proportion to diameter, has been developed by the Micromatic Hone Corp. One motor mounted on the spindle housing powers both the rotation and reciprocation motions. The machine has a positive mechanical adjustment, through an eccentric, to give strokes of any length up to 2 inches. Two stages of tool expansion are used: initial expansion results from a direct hydraulic thrust; the final, Microdial, expansion is a mechanical-feed expansion operated and controlled hydraulically. The tool is expanded to rough bore size at the bottom of the first honing stroke by oil directed to the top of the initial expansion piston, drawing below. During honing, this piston is locked in place by a pin entering a bayonet lock. To completely collapse the tool, hydraulic pressure must be directed to the bottom of the piston. During the Microdial expansion a hydraulic ram, through a mechanical linkage and gear train, rotates a threaded sleeve surrounding the upper spindle bearing. This threaded sleeve causes a threaded bearing outer race to move down and expand the tool at a controlled, positive rate. The machines will hcne any bore less than 4 inches in diameter and under 2½ inches in length.





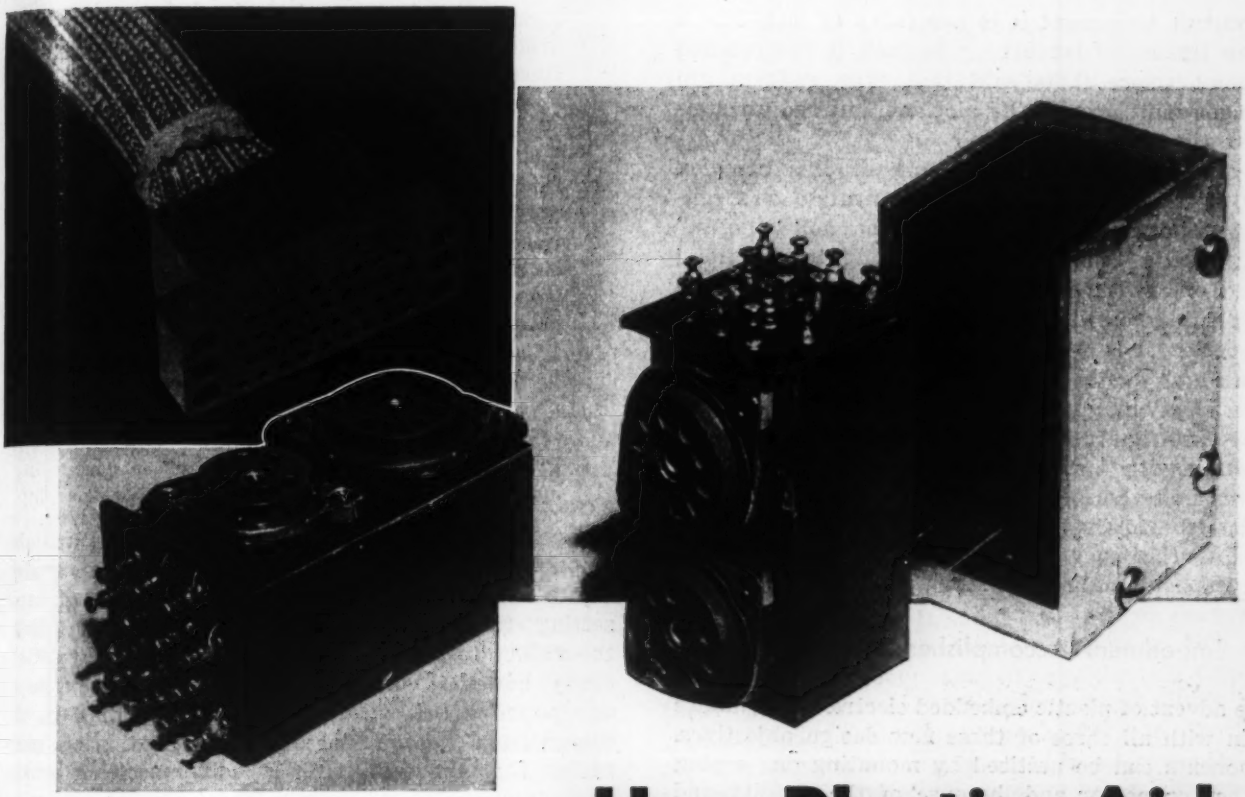


Fig. 1—Top—Delicate leads soldered to miniature terminals are sealed and strengthened by plastic embedment. Above and Right — Two-tube circuits miniaturized to a high degree

How Plastics Aid Miniaturization

. . . of electrical assemblies in aircraft

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A CONTINUALLY mounting demand for miniaturized assemblies of light-weight electrical and electronic apparatus is confronting design engineers. The aircraft electrical designer especially is faced with the problem of utmost miniaturization and the attendant problem of close electrical spacing. Conventional construction of miniaturized assemblies results in increased danger of failure from the effects of vibration, dust and dirt particles, and condensation. Even more serious in high-altitude aircraft and guided missiles is the rapid degeneration of air as a dielectric with increasing altitude. The flashover value for air, which has a poor dielectric strength (30 volts per mil) even at sea level, is further reduced by a factor of 3 to 4 at 45,000 feet and by 9 to 10 at 60,000 feet.[1] The answer to these conflicting demands of miniaturization and reliability under adverse conditions is frequently provided by new synthetic-resin formulations.

Natural and synthetic plastic materials in the form of "potting" compounds, "hot melts" and impregnating resins are not new in the electrical industry, having been used for some years to provide insulation and mechanical support to electrical or electronic components. It was in the development of the World War II radio proximity fuse, with its almost unbelievable requirements of mechanical shock resistance and compactness, that a tremendous impetus was given to the exploitation of synthetic resin formulations in which entire electronic circuits could be embedded. Perfection of this technique saw the advent of sealed units of extreme ruggedness and excellent electrical properties.

The ability to produce self-supporting sealed assemblies of electrical components came at a time when the electronic industry was evincing increased interest in two design concepts, miniaturization and unitization. For the aircraft electrical manufacturer, a third concept has become increasingly important, especially in military aircraft, namely the use of hermetically sealed units. The concept of miniaturization was forced upon the military aircraft designer as a result of the unprecedented amount of electronic

[1] References are tabulated at end of article.

and control equipment it is necessary to install in a modern fighter or bomber.[2, 3] In fact, it has reached the point where it is said that "the gadgets are no longer built around the airplane, but the airplane around the gadgets."

In order to facilitate servicing of this complex array of equipment the idea of unitization was conceived. Equipment is assembled from small "plug-in" units, usually broken down according to function.[4] Instead of the time-consuming servicing process required for conventional equipment in the event of malfunction, it is only necessary to isolate the defective unit and plug in a spare. To insure that the units will be functioning when ready to use, to protect them against dust and dirt during storage, and to prevent tampering with factory adjustments, it is natural to seal the units hermetically. To the aircraft designer this has the further advantage of protection against electrical flashover at high altitudes and against moisture condensation from temperature changes.

Embedment Accomplishes Objectives

The advent of plastic-embedded electrical assemblies tied in with all three of these new design objectives. Components can be unitized by mounting on a plug or other connector and, because of the rigidity and high insulation value of the plastic, can be miniaturized to a degree unattainable in conventional construction. The plastic, applied to the assembly as a free-flowing liquid which fills every space and later solidifies, forms an almost perfect hermetic seal and one that is not subject to later leakage.

These structural and electrical insulating materials are now commercially available in liquid form, and as such may be used either to embed delicate close-spaced electrical components by the use of simple open molds on the bench, or for apparatus which must be assembled "in-place" on the airframe. The assembly is effectively and rapidly sealed without the use of any apparatus for heating or pressurizing. The component to be sealed may be simply a single terminal or miniature connector to which are attached fine and easily-broken leads, or it may be an entire complex electronic circuit.

Experience has shown that the following properties are desirable for resin formulations used in airborne equipment:

1. The monomer must be liquid to completely permeate the unit to be sealed
2. The polymerizing reaction must be initiated at room temperature and pressure. It must not generate a temperature high enough to affect electronic components (185 to 200 F)
3. Solidification must take place more or less rapidly (½ to 6 hours) so as not to require a large mold inventory or to hold up production. A complete "cure"—chemically, mechanically and electrically—must take place at room temperature within a reasonable time, say 24 hours
4. The final casting must provide a good hermetic seal. It must not be affected by moisture or water, oils, gasoline or other solvents encountered in end use
5. The casting should be mechanically strong and rigid. It should be capable of being sawed, filed, drilled and otherwise machined for mounting or finishing. Shrinkage on polymerizing should be minimized
6. The resin should be thermosetting. It should not melt or be grossly distorted or degenerated by any temperature likely to be encountered
7. Mechanical properties—coefficient of expansion, thermal conductivity, thermal shock and tensile strength—should be such that embedments can withstand low temperatures as well as high temperatures without failure
8. It should have high dielectric strength (300 to 400 volts per mil), good insulation resistance (comparable to phenol-formaldehyde resins), and ideally low dielectric constant and loss factor
9. Preferably it should be transparent to permit inspection of embedded components or workmanship

As might be expected, commercially available plastic monomers do not meet all of these requirements an equally high degree. The property of rapid setting, for example, usually is not compatible with the ability to produce large crack-free castings. Generally however, when a quantity of resin in excess of one pound is required, something is lacking in the design from a standpoint of miniaturization or unitization (i.e., the unit could be compressed or broken down into smaller subunits). The temperature range[5] at present is not compatible with transparency. In

Fig. 3—Right—Two-tube electronic circuit is mounted and embedded on a miniature plug base

order to provide thermal conductivity for relief of thermal strains it is often necessary to add fillers, which not only impair transparency, but also may increase the dielectric constant and power factor. In general, this confines present use of plastic-embedded circuits to the frequency range below 50 megacycles.

The somewhat sensitive nature of many electrical components makes it necessary to convert these embedding resins from the liquid to the solid state at room or only slightly elevated temperatures and without the aid of pressure. Perhaps the first-used and best-known of these room-temperature polymerizing formulations was NBS Casting Resin,[6] developed by the National Bureau of Standards for the proximity fuse. Essentially a mixture of styrene and dichlorostyrene polymers, it possesses superior electrical properties at high frequencies, but lacks many desirable design features such as availability, ease of preparation and short polymerization time. Preparation of embedments of NBS resin requires critical control, together with considerable skill. Furthermore, the resulting casting, since it is a styrene polymer, is thermoplastic rather than thermosetting, which severely limits its useful temperature range.

Interest shown in NBS Casting Resin led to the development of thermosetting liquid monomers more easily prepared and handled. These commercially available monomers are mainly blends of various polyesters and styrene and, although having a greater high-frequency loss factor than NBS resin, share with it the virtue of solidifying to a strong, rigid casting of high electrical insulation value. With the proper selection of catalyst and/or promoter this transformation takes place spontaneously at room temperature. Heat necessary for cure of the resin is generated by the polymerization "chain-reaction" itself. The fact that no ovens or presses are needed to cure these resins extends their use to many manufacturing processes hitherto beyond reach.

Fig. 2—Left—Space considerations often demand the use of miniature connectors

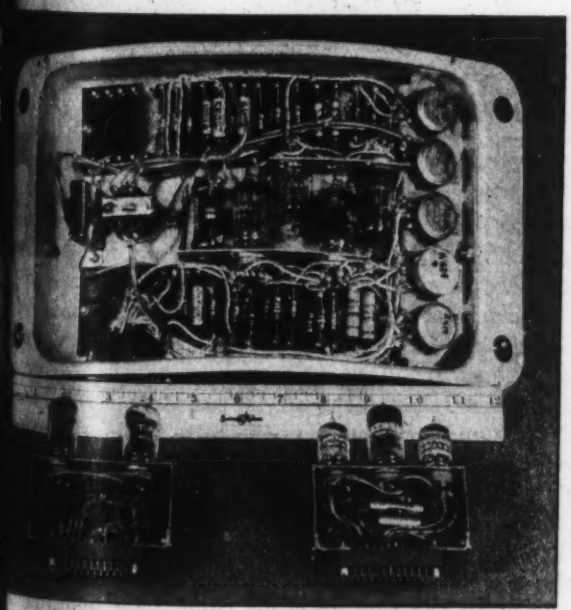


Fig. 4—Above—Large amplifier shown at top is compressed into a much smaller space by miniaturizing and separating into two plug-in units

Commercial Formulations Available

Although a number of firms active in the field have gone to the extent of producing their own formulations,[7] such a step probably is not justified since a fairly large number of chemical manufacturers are selling suitable resins, and some are anxious to cooperate in electrical applications. Among those known to the authors are Rohm and Haas, Pittsburgh Plate Glass, H. H. Robertson, U. S. Rubber, Emerson and Cuming, and Melpar Inc., the last two producing resins specifically for electronic application. Bell Aircraft Corp. is actively engaged in evaluating many of these products in combination with fillers and catalysts and, considering the activity in the field, expects to have increasing numbers of new products available to evaluate. To date, however, two groups of resins have proved to be of general usefulness and will serve to demonstrate specific applications.

Representative of the first group are the Selectron resins, particularly No. 5003, a rigid member of the series, produced by the Pittsburgh Plate Glass Co. The resin is used in combination with peroxide catalysts and a few drops of "promoter," usually diethylaniline. Prior to use the Selectron may be mixed with 25 per cent by weight of talc, which greatly enhances temperature resistance of the finished casting.

The second resin is Robertson Stypol 507E. This formulation contains talc filler milled-in by the producer (presently the Mellon Institute, where it was developed for transformer encasing) and requires only the addition of Luperco JDB catalyst (produced by the Lucidol Division of the Novadel-Agene Corp.).

In comparison with the Selectron-talc formulation the Stypol is slower setting (several hours, compared with less than one hour), has a higher rate of shrinkage, and has lower insulation resistance. However, it has a lower exotherm (peak reaction temperature) and consequently can be used on larger castings without danger of destructive cracking. Having only two components, it is simpler to use and less critical. The high and low temperature resistance of a typical embedment is somewhat broader than Selectron-talc. Typical formulations using Selectron and Stypol, respectively, are:

Selectron 5003	60 grams
Talc (No. 10 grade)	20 grams
Luperco ATC	1.1 grams
After mixing, add	
Diethylaniline	4-6 drops
and	
Stypol 507E	100 grams
Luperco JDB	1.5 grams

Application of the embedment technique falls into

one of three principal categories:

1. Mechanical support and protection (sealing)
2. Electrical and thermal insulation
3. Circuit packaging.

In the first category, an application developed and used extensively by Bell Aircraft Corporation is the sealing of cables to miniature and AN-type connectors. In the majority of electrical work performed on aircraft and guided missiles, space considerations demand the use of miniaturized connectors and preclude use of conventional hoods and cable clamps. Delicate leads soldered to miniature terminals are extremely vulnerable to breakage in the field and during factory testing operations. The sealed type of connection shown in *Figs.* 1 and 2 solves the problem by providing an extremely rugged termination. A further advantage lies in the complete freedom from entrance of dirt, metal chips and moisture.

High Voltage Presents Problems

In the majority of connectors so treated, very high voltage is not present, hence high-altitude flashover is not a problem. Where this may become a problem the plastic provides complete substitution of solid insulation for air and so prevents flashover.

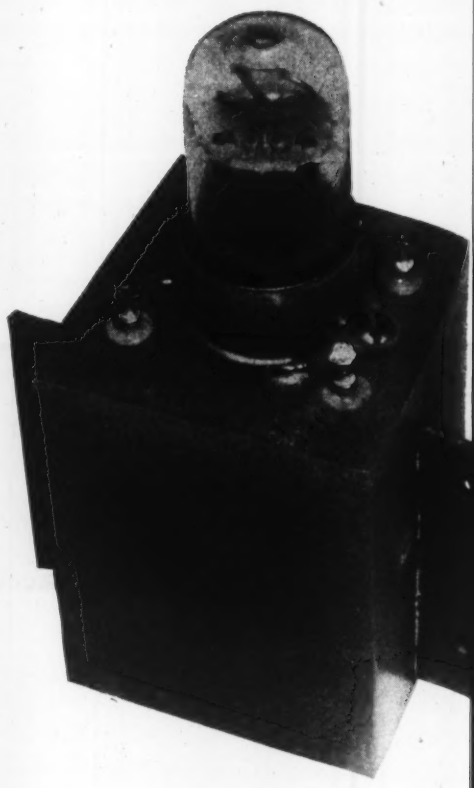
Altitude tests on a magnetron operating at 2½ kv led to a second-category application. Breakdown was experienced from the high-voltage lead to the case at undesirably low altitudes. A Selectron collar cast around the lead eliminated the short air path, permitting full operation at the desired altitude.

In another application, a solenoid was fitted inside a steel case with a fine pigtail lead emerging from a hole in the metal cover. Spacings were so small as to permit flashover under a 1000-volt hipot test, even though an insulated bushing surrounded the lead. A single drop of Selectron placed in the hole enabled all solenoids to pass the test and made the design considerably more rugged.

In a 28-volt heater for aircraft use, a special odd shape was desired in a minimum of procurement time. A decision to produce the heater at Bell Aircraft, using the Stypol formulation for electrical and thermal insulation, has led to large-scale production of this unit. In the manufacturing process a thin film of resin is laid down on the metal can, which acts as a heat-conduction path and a mold. Nichrome wire, wound around an impregnated Fiberglas form, is placed in the insulated can and the assembly is completed simply by filling the can with Stypol formulation.

Examples of the third category, electronic circuit embedment,[5, 7] have been so well covered in recent publications that they will not be enlarged upon here. Essentially, this category is a combination of the first two, i.e., the provision of mechanical support and hermetic sealing plus electrical insulation. Thermal insulation is usually undesirable, and metal mounting plates or similar means should be provided to dissipate heat from packages running at high watt densities. Examples of this type of design are shown in *Figs.* 3, 4 and 5. The first is a two-tube circuit mounted on a miniature plug. *Fig.* 4 shows the space saving obtained by miniaturizing and separating into two plug-in units the larger amplifier shown above in the same illustration. These two plug-in units, miniaturized to a still-greater degree, are shown in *Fig.* 1.

Only a small amount of equipment is required for the utilization of these plastics. For moderately large production it consists of little more than a bench and scales, as shown in *Fig.* 6, for weighing out ingredients. In applications at Bell Aircraft it has been found simplest to weigh out batches of about 60 grams and dispense them to the men doing the actual em-



bedding. The catalyst of the Selectron mix is added in advance since the mixture has a long pot life, and the promoter is added just prior to use. For more exacting work, such as circuit embedment, it is desirable to have a vacuum deairing setup, which may be simply a bell jar and a vacuum pump. The user should be cautioned against too prolonged deairing, as the styrene component of the resin may evaporate off. The liquid monomers are usually soluble only in acetone, therefore it has been made a practice to weigh out the materials in paper cups and thus eliminate a washing-up operation.

While the catalyst may be easily mixed in by hand, an electric stirrer or jar mill is more convenient for incorporating the talc or other filler. Hot spots and cracking will occur during gelation if the catalyst has not been thoroughly stirred into the monomer. A variety of pigments may be mixed into the monomer at the same time as the talc to provide a color code for electrical connectors. Pigmented castings should be tested carefully for insulation resistance and dielec-

tric strength, as some pigments have a deleterious effect on the electrical properties of the resin.

Molds can be fabricated of almost any smooth material except rubber and copper, which inhibit polymerization. This wide choice of materials greatly increases the versatility of the process and permits ready improvisation. The smoother the mold surface the better the results. For larger castings metal molds, preferably aluminum, are needed to dissipate the heat of reaction. Sometimes a sheet of glass can be used for the bottom of the mold and the sides built up of sheet aluminum. Some miniature connectors have a plastic screw-on hood which, by enlargement of the cable entrance hole, can be used as a mold and then removed or left in place. Permanent metal molds must be kept clean by wiping with acetone or brush-wash after use. A light coating of Dow-Corning DC-4 silicone or other mold-release compound helps to prevent sticking.

When designing molds it is essential to remember that they must have watertight joints. The liquid monomers have a low surface tension and, while they are viscous, will flow through almost any fissure. A satisfactory solution has been found in joint sealing

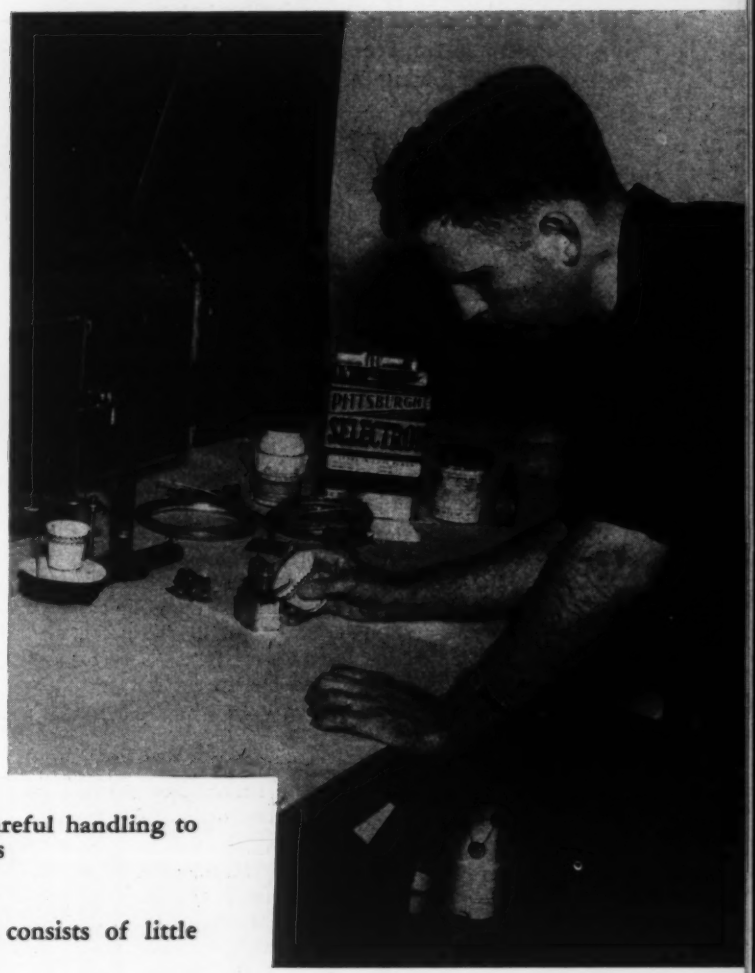


Fig. 5—Left—Tube sockets or female connectors require careful handling to prevent plastic from flowing into contacts

Fig. 6—Above Right—Equipment for plastic embedment consists of little more than a bench and scales

with vacuum wax or DC-4. Fine asbestos or glass fiber may be added to the monomer to increase viscosity and prevent flow, even into large openings. The addition of fiber, however, will increase the absorption of the casting, hence is to be foregone whenever possible. Use of threaded parts should be avoided in mold design since the monomer will flow into threads and freeze the screw. When designing two-piece molds the use of external clamps and polished mating surfaces is to be preferred.

Generally speaking, in designing embedments it is best not to have parts projecting from the mold on more than one side, since this complicates the mold-sealing problem. If female connectors or tube sockets, *Fig.* 5, are to be part of the embedment, care must be taken to prevent liquid resin from flowing into the contacts. Smearing with DC-4 or wax and assembling to the corresponding male part during casting will suffice. However, sealing and miniaturization considerations make it preferable to embed the entire tube, especially subminiatures, when heat dissipation limitations permit. This is in accordance with the principles of unitization, since it is easier from a maintenance standpoint to replace an entire plug-in unit. Tubes to be embedded should be coated with a protective silicone rubber, such as Melpar's Melcoat or Silastic 181, to decrease their vulnerability to stresses set up by temperature changes.

Embedments can easily be designed in special shapes, *Fig.* 7, to facilitate mounting or assembling into larger packages. For more conventional mounting, studs or spacer tubes can be cast into the mold for tiedown points. Probably the best design is to build up the components on a male connector and cast the entire assembly with the plug upward. The plug then provides both mounting and electrical connection. If necessary, castings can be drilled or machine-finished for mounting, or even repaired by dental techniques.

Although almost any component can be embedded, including even potentiometers and trimmer capacitors, certain pressure-sensitive elements should not. For example, one particular subminiature tube had a weak end-seal which invariably failed.

Since new resins are being developed constantly and are required to have different properties for a variety of end uses, an adequate evaluation program is necessary, both as a preliminary to setting up an embedment program and to remain abreast of developments in the field. Although the suppliers of resins are willing to furnish considerable information concerning electrical and physical properties, the variables of filler and casting conditions and the nature of the particular embedment necessitate tests in the user's own laboratory.

At Bell Aircraft Corp. certain test procedures have

aided in the evaluation program. Although this testing program is far from complete, its nature is indicated by the following tests:

1. *Temperature Resistance.* In the temperature resistance test, 1½-inch cold-rolled steel rounds of ½-inch diameter are embedded centrally in a 2 by ¾ by ½-inch mold. Test pieces are brought to successively lower temperatures until failure occurs by cracking. Another piece is subjected to higher temperature until failure. Typical ranges are −80 to +350 F on talc or mica-filled pieces.
2. *Dry D-c Resistance.* In the d-c resistance test, a one-inch cubical mold is fitted with electrodes of accurately-known diameter and spacing. The d-c resistivity is measured on a 500-volt megohm bridge. Values of from 3 times 10^{10} to 5 times 10^{11} ohm-cm^3 have been observed, which is in the range of Bakelite-type plastics.
3. *Humidity Resistance.* The aforementioned cubic test piece is held in a test chamber at 90 to 95 per cent humidity and 150 F temperature for 150 hours. The loss in d-c resistivity is a measure of moisture penetration and hence of hermetic seal quality. This test is preferred to conventional water-absorption figures, as it directly determines the important quality, namely insulation resistance.
4. *Dielectric Strength.* After drying, the test piece can be tested for dielectric breakdown for a-c or d-c. Results should be on the order of 300 volts per mil or higher.
5. *Dielectric Properties.* Power factor and dielectric constant can be measured on a Q-meter by conventional techniques after forming a capacitor from a thin layer of the plastic.
6. *Temperature Tests.* An exotherm measurement should be made of the first batch of any complex casting made. This is most easily performed by means of a thermocouple embedded in the plastic, and serves as a check on the correct amount of catalyst and promoter used. High exotherms must be avoided, not only because of the danger of harming temperature-sensitive components, but because high exotherms lead to cracked castings. If vacuum tubes or power resistors are embedded, thermocouples should be affixed to them. Subsequent temperature measurements during operation tests of the circuit will determine whether the component is being adequately cooled. Thermocouple leads may be clipped off when measurements are complete.

Costs of the embedding process appear to be quite low compared to competitive techniques. It has been estimated that the cost of embedding a two-tube unit containing a transformer is less than the cost of placing the transformer alone in a hermetically sealed can.[8] The materials run from about fifty cents to several dollars per pound, and the equipment investment is low. The cost of embedment in many cases is far less than the assembly of components in conventional metal chassis and housings which cannot give comparable protection. Single components such as small switches, which are enclosed but not hermetically sealed, can often be advantageously embedded at a cost of only a few cents.

Special Training Desirable

Training of men to perform in-place or bench embedment does not present any serious problem, although it appears best to have a chemically-trained person to perform evaluation tests and to prepare master batches.

The effect of the embedding technique on design and manufacturing processes is bound to be increasingly great as the need for sealed units for the armed forces increases and the resins themselves are improved. While some of the methods described are unconventional, both the cost and the performance justify their wider use. In particular, the idea of in-place embedment in manufacturing electrical and electronic apparatus is certain to spread. It is believed that there are many nonelectrical applications that will also appear in future designs as the properties of the materials described become better known.

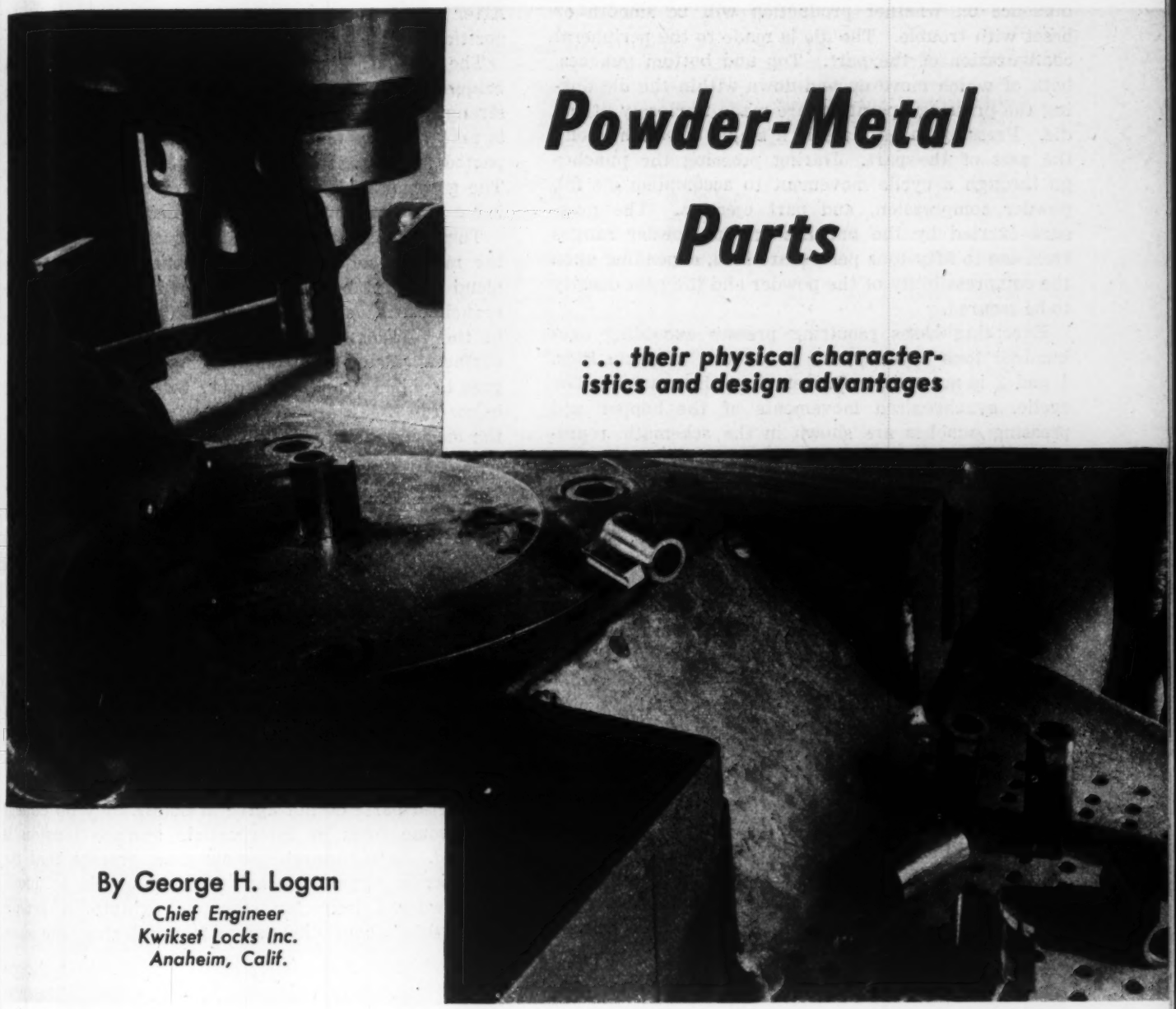
References

1. M. J. DeLerno—"Potential Breakdown of Small Gaps Under Simulated High-Altitude Conditions," *Trans. AIEE*, Vol. 63, March, 1944. Page 109.
2. W. H. Hannahs and B. S. Eblefson—"Miniaturization—Crux of Contemporary Products Design," *Electrical Mfg.* June, 1950.
3. L. V. Berkner—"The Military Dilemma Imposed by Electronic Maintenance," *Proceedings of Symposium on Improved Quality Electronic Components, Washington, D. C., May* 9-11, 1950, Trielectro Co., Washington, D. C.
4. C. Brunetti—"Electronic Design Trends and Techniques," Reference 3.
5. M. L. Miller—"The Design of Electronic Equipment Using Subminiature Components," *Proc. of the IRE*, Vol. 38, Pages 134-135.
6. "Development of National Bureau of Standards Casting Resin," *NBS Circular* 493, National Bureau of Standards, Washington, D. C.
7. W. G. Tuller—"Potted Subassemblies for Subminiature Equipment," *Electronics*, Vol. 22, Sept., 1949, Page 104.
8. W. G. Tuller—"Recent Developments in Potted Circuits." Reference 3.

Fig. 7—Special shapes to facilitate mounting or assembly can easily be cast in plastic

Powder-Metal Parts

. . . their physical characteristics and design advantages



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MANY facets to the study of powder metallurgy are pursued with the test tube, the analytical balance, the microscope; indeed, with all of the tools of a research sanctum. These studies, however, but nurture the practical application of powder metallurgy: Fabrication of superior, less costly parts for machines or products. It is a method the creative design engineer cannot afford to ignore.

Although powder metallurgy is well established, there exists among some designers sparse understanding of its potentialities. This article proposes to outline important considerations relating to the practical side of the technique and to answer the logical first questions asked by an intrigued designer: How are parts made from powder metal? What are representative applications? What are prime advantages of the method?

Fine granules of metal powder furnish the raw stock for the process. These powders are made from a variety of parent metals, such as iron, copper, tin, lead, zinc, nickel, and graphite. Blends of two or more of the elements often produce familiar alloys, such as steel, brass, bronze, or nickel-silver. On occasion, the desired part characteristics are best obtained through using prealloyed powders. Thinking of brass in the latter category, for example, each individual powder particle is actually brass as an alloy of copper and zinc. Usage of aluminum powders has lagged due to practical pressing difficulties, but these obstacles are rapidly being overcome through research and experimentation.

In preparation for production, precise punches and a die are made. The design, manufacture, and installation care applied to this tooling has a major

Fig. 1—Above—Powder-metal briquettes of lock cylinders being formed automatically on a production press

influence on whether production will be smooth or beset with trouble. The die is made to the peripheral configuration of the part. Top and bottom punches, both of which move up and down within the die during the pressing operation, are made to closely fit the die. Pressing takes place in a single direction, along the axis of the part. During pressing the punches go through a cyclic movement to accomplish die fill, powder compression, and part ejection. The pressure exerted by the punches on the powder ranges from ten to fifty tons per square inch, depending upon the compressibility of the powder and the part density to be secured.

Excepting cases requiring presses exceeding one-hundred tons capacity, the production of parts *Figs.* 1 and 2 is automatic after starting the machine. The cyclic, synchronized movements of the hopper and pressing punches are shown in the schematic representation of the molding process in *Fig.* 3.

During the fill portion of the pressing cycle the upper punch remains retracted as shown. The lower punch descends to its fill position. Concurrently the hopper (not illustrated) moves over the die cavity and fills it. Thereupon the hopper rotates clear of the punch's action-line. To initiate the compression part of the cycle, the top punch moves down into the die while the bottom punch remains stationary. The top punch thereby partially compresses the powder stacked above the bottom punch. Then the top punch remains stationary while the bottom punch moves upward, completing compression of the powder.

The final phase of the part-forming cycle is ejection. First, the top punch moves upward to its retracted position. This motion is followed by upward movement of the bottom punch, sufficient to lift the part to the die table surface. A sweep (actually part of the hopper structure) pushes the part across the die table. The sweep returns to its neutral position. After ejection, descent of the lower punch to its fill position begins the next pressing cycle.

The compact ejected from the die is known as a briquette; in this form the part is called "green". Its strength is low, but it can be handled. The briquette is ready for the sintering operation wherein the compacted particles are strongly bonded together by heat. The green parts are placed on a moving belt traversing a sintering furnace at controlled speed.

Therein they are subjected to a temperature below the melting point of each constituent of the powder blend to effect bonding of the particles. An inert or reducing atmosphere, or a vacuum, is contained within the furnace to prevent oxidation of the particle surfaces. Before the compacts leave the furnace they pass through a cooling chamber where they are cooled below the oxidizing temperature. A flame curtain at the entry to and exit from the furnace excludes oxygen from the sintering and cooling chambers.

If unusually close tolerances are not involved, the pieces are used as sintered. Although they are somewhat lighter than solid metal they have practically equivalent appearance, high strength, ductility, and hardness. When exceptionally close tolerances are required, of the order of 0.002-inch or less, it is necessary to use a sizing or coining operation on the sintered parts.

Powder-metal parts may be treated with the familiar finishes for appearance or protection. Electroplating, staining, lacquering, and baked-on enameling produce excellent finishes.

Although theories to explain the strength of powder-metal parts do not agree in detail, they do concur that some form of interparticle surface tension is created. It is through the sintering process that the remarkable strength is achieved. A green briquette of powdered iron, for example, exhibits a tensile strength of about 1000 psi. After sintering, the same

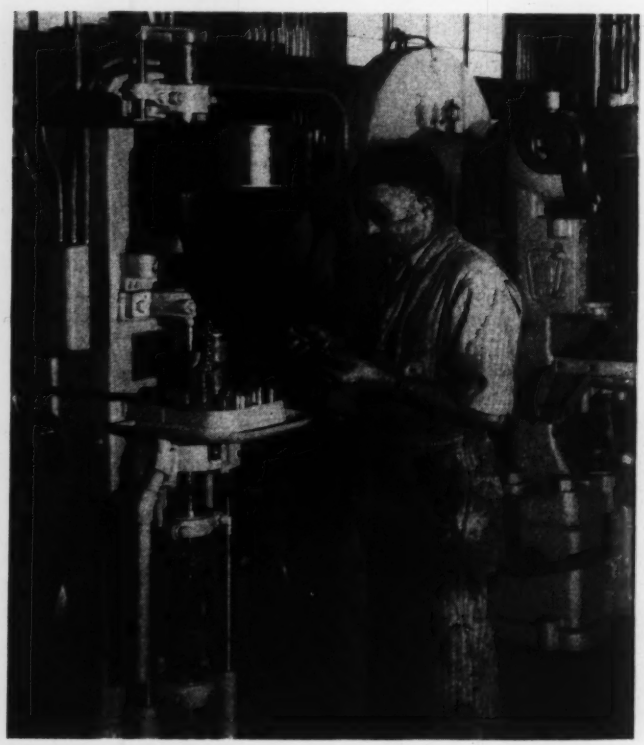
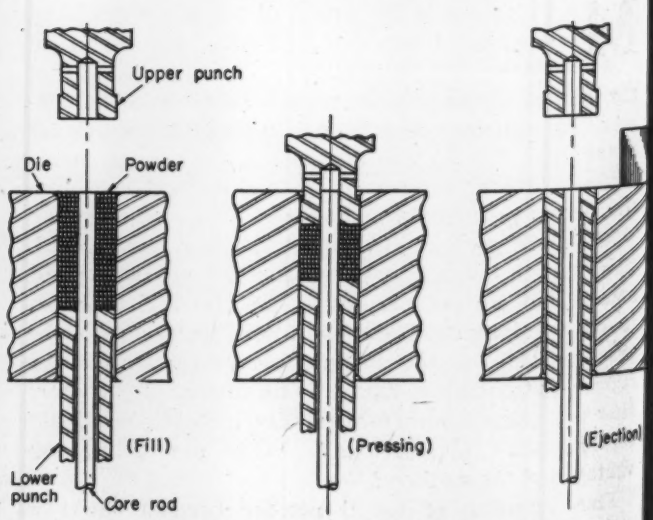


Fig. 2—Left—Typical powder-metal press in operation

Fig. 3—Below—Diagram of punch positions during filling, pressing and ejection phases of producing green powder-metal briquettes



Comparative Properties of Sintered and Treated Powder-Metal

Powder-Metal Part	Chemical Composition Sn (%)	C (%)	Zn (%)	Cu (%)	Pb (%)	Fe (%)	Type of Iron Powder†	Density of Part (%)	Condition of Part	Physical Properties Tensile (psi)	Yield (psi)	Elong. (%)	Red. Area (%)	Hardness (Rockwell)	Shear (psi)
Steel	...	½-1¼	..	5-7	...	87-92	*P*		as sintered	70,000	60,000	1		40-60B	55,000
									heat treated	110,000	*	0	0	10-35C	88,000
							H		as sintered	45,000	35,000	1		30-70B	35,000
									heat treated	65,000	*	0	0	10-35C	52,000
Iron	...	...	..	...	...	100	*P*		as sintered	20,000	10,000	15		40-80F	16,000
									carburized	60,000	*	0	0	20-45C	48,000
							HX	95-97	as sintered	60,000	50,000	25	30	30-70B	48,000
									cyanide hardened††	75,000	65,000	10	15	20-45C	60,000
									carburized§	80,000	60,000	10	15	40-85B	64,000
							PX	95-97	as sintered	115,000	75,000	5	10	15-30C	92,000
									carburized§	140,000	*	0	0	45-60C	112,000
Brass (Leaded)	...	...	20	78.5	1½	...	..		as sintered	32,000	28,000	20		10-50F	25,000
									repressed	48,000				0-50B	
Bronze	9.5-10.5	...	..	87.5-90.5	<1.5	...	..	82‡	as sintered						*K*=22,500**

† Key: *H* denotes hydrogen reduced iron; *P*, electrolytic iron: *X*, infiltration of iron with copper liquefied at sintering.
* No appreciable yield point.
§ Carburized to 0.060-inch case.
†† Cyanide hardened with 0.010-inch case.
‡ Min. density, or 6.4-6.8 g/cc.
** Radial crushing strength, $P=(KLt^2)/(D-t)$, in which P=Radial Crushing Strength, (lb); D=OD of part, (inches); t=Wall thickness, (inches); L=Length of part, (inches); K=Strength constant.

part will range in strength from about 70,000 to about 115,000 psi.

Tungsten provides an interesting example of high tensile strength in powder metallurgy. The melting point of tungsten is too high for practical handling by any method other than the powder-metal process. In this process tungsten is powdered, cold pressed into blanks, and sintered. The blanks are hot worked and drawn into wires for electric filaments. These exhibit the amazing tensile strength of 600,000 psi.

With the powder-metal technique, tensile strength, ductility, and impact resistance are controllable characteristics, although their upper values tend to be somewhat less than those for solid metals. Powder-metal part porosity, controllable within a wide range but never susceptible to complete elimination, is the reason for the lessening of these values. But it is generally realized that many solid metal machined or otherwise formed parts are perhaps twenty to thirty times as strong as their function demands.

By blending iron powder with copper and graphite (carbon) powders to form steel alloy powders, tensile strengths as high as 70,000 psi can be attained. Such pieces can be further strengthened and hardened by conventional methods of heating, quenching, and tempering; and by nitriding, carburizing, or cyaniding. These treatments raise tensile strength to the order of 100,000 psi.

The chemical composition of powder-metal parts is purer than analagous solid metal units. Moreover, the percentages of the constituents in a powder-metal blend are conveniently precision controlled.

The susceptibility of powder-metal parts to oxidation or other chemical attack is essentially the same as that exhibited by corresponding-alloy solid metal parts. Corrosion protection of electroplating is as effective as with solid metal parts. Ferrous powder-metal parts own an advantage over the same parts made from solid metal in that the former can be subjected to a simple, inexpensive corrosion resistant treatment not applicable to the latter. This treatment is oil impregnation of the powder-metal parts, after sintering. The porosity makes this treatment possible. The oil forms a protective film, resisting corrosive attack. This method is not equivalent to plating but is satisfactory for requirements of lesser severity, and its cost is relatively low.

An almost limitless number of blends of different kinds of metal powders produce a wide assortment of alloys. A few of the most frequently used blends are itemized in the accompanying tabulation. The blend symbols are classified by the following key: *H* denotes hydrogen reduced iron powder; *P* denotes electrolytic iron powder; *X* denotes infiltration of iron powder with copper liquefied at sintering, producing a part of 95 to 97 per cent density.

Actual surface hardness, and hence wear resistance, is always greater than direct Rockwell C measurements indicate. The porosity of powdered metal parts, permitting the diamond to sink farther into the material, is the reason for such readings being misleadingly low. For example, sintered and heat treated steel parts made from electrolytic or hydrogen-reduced iron powder (types *P* or *H* in the table) are actually file hard, corresponding to Rockwell hardness of 50 to 60C instead of 10 to 35C as tabulated.

The as-sintered iron composition provides a ductile iron part which has low strength and hardness, but which exhibits the ability to take deformation. This characteristic is useful where the part is to be swaged, staked, or riveted to another component to form an assembly.

Infiltration (type *HX* or *PX*) is accomplished by placing pellets of copper on the briquette as it enters

the furnace. The copper melts, permeating the pores, and thereby raises the part's density, strength, and hardness. Characteristics acquired through infiltration of iron briquettes by liquefied copper are shown in the table.

A typical brass and bronze are also tabulated. Repressing nonferrous powder-metal parts increases the ultimate tensile strength approximately 150 per cent of that as sintered, and the hardness range to Rockwell 0 to 50B.

Economical conversion to powder metallurgy has manifold opportunities for parts originally planned to be cast, forged, stamped, or machined. Frequently, a single powder-metal part can replace an assembly of solid metal parts. For some parts the ultimate configuration may not be obtainable by this method alone; but necessary second operations can be reduced in number. Often it will be possible to show a net saving in part cost.

Certain types of special parts, not practicably produced by other methods, are easily fabricated as powder-metal parts. Different metals, or metals and nonmetallic substances, may be combined to produce features which cannot be secured by mechanical joining or chemical alloying. Typical of such products are:

1. Lead combined with copper for a bearing surface. Lead contributes an antifriction property and copper contributes strength
2. Copper combined with carbon, typified by commutator brushes. Copper increases conductivity, carbon supplies antifriction properties
3. Attachment of pigtails to commutator brushes during the pressing operation
4. Oil suspended in porous regions between metal granules to provide continuous lubrication
5. Copper or silver combined with tungsten to produce contact points. Copper or silver increases conductivity, tungsten contributes resistance to heat and wear
6. Combination of tin, copper, iron, lead, graphite, asbestos, and silica to produce heavy-duty friction surfaces.

Typical Machine Applications of Powder-Metal Parts

Ball bearing cages	Guides
Brushes, motor	Instrument parts
Cams	Levers
Chain links	Lock parts
Clock parts	Magneto weights
Contact points	Magnets
Cylinder liners	Nozzles
Detents	Oilless bearings
Electric razor heads	Oil-pump gears
Electrical parts	Pawls
Electrodes	Piston rings
Electronics coil cores	Ratchets
Filters	Rollers
Friction facings	Rotors
Gaskets	Turbine blades
Gears	Valve guides

The foregoing special applications have solved problems which resisted solution through consideration of more familiar processes. Several of these examples employ combinations of metals which are unalloyable chemically. If alloying is attempted the elements tend to separate because of incompatibility, but through the powder-metal technique the finished part exhibits the characteristics of each component.

Controllable porosity of powder-metal parts is a valuable unique characteristic even though it entails a reduction of tensile strength in comparison with the solid metal. The oilless bearing is the most widely known example of porosity advantage. Such bearings are impregnated with oil after sintering. The minute interstices between the metal particles provide a long-life reservoir for the lubricant, and act as channels through which capillary action draws the lubricant to the bearing surface. Such bearings hold 10 to 25 per cent of oil by volume. They function automatically, supplying more lubricant to the working surface as heat expands the oil and reabsorbing the oil as it cools.

Use of oilless bearings in the automotive field is common knowledge. They are also employed advantageously in numerous other applications. They have remarkable value in textile, paper, and laundry machinery where oil contamination of the product cannot be tolerated. Household appliances need not be periodically oiled, nor must the bearings be accessible for oiling, when the appliances are equipped with oilless bearings.

Advantages of Powder Metallurgy

Use of powder metallurgy is by no means a production panacea. It has limitations, as do all manufacturing operations, but it is worthwhile to note the salient points in its favor.

Usually tooling cost can be amortized over as few as 10,000 parts and a cost per part saving shown. In some cases, where a multiplicity of machining operations are eliminated, as few as 500 parts will amortize the die and punches with cost advantage. Tooling set-up time is of the same order of magnitude as required by punch press dies.

Production rates are high. Dependent upon the size of the press and the part, more than 15,000 parts per hour are obtainable. Operator skill necessary is moderate; thus labor cost is conservative. The reduction or entire elimination of second operations obviously minimizes production costs.

With scrap loss eliminated, materials purchased can be quantity-and-cost estimated accurately. Porosity, density, weight, and strength are susceptible to accurate predetermination in the planning stage.

Large factors of safety which may be inherent with use of solid metal stock can be held to reasonable values in powder metallurgy with attendant economy. Parts thus made are usually lighter than the same composition parts of solid metal. Weight reduction, of course is frequently important.

Powder metallurgy is establishing a continuously expanding foothold in the machine and product fields. It should not be overlooked by the engineers responsible for overall and component design.

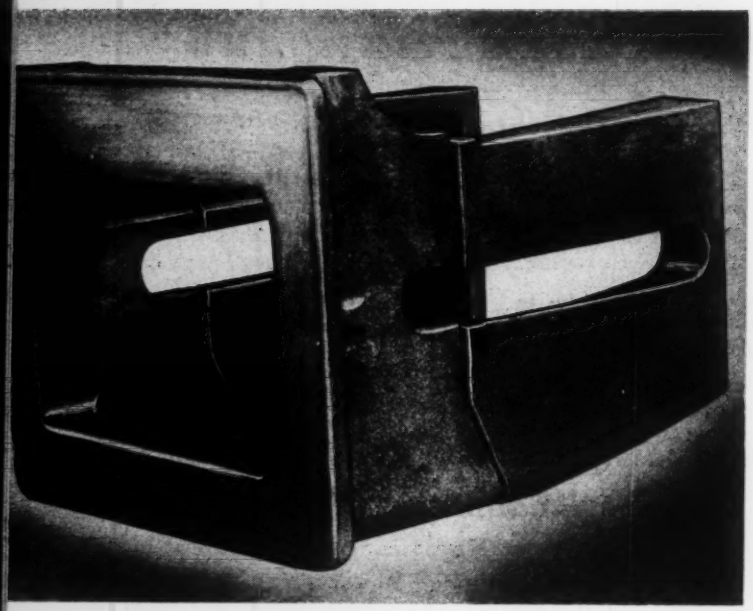
CAST-WELD DESIGN

Key to low-cost steel castings having greater precision and serviceability

CAST-WELD construction techniques are gaining wide general acceptance as the key to many complex design problems and the practical solution in many cases of possible controversy over the relative merits of weldments and steel castings. Instead of using integral steel castings or structures built up of a number of pieces of rolled steel, in numerous instances manufacturers are producing parts composed of several steel castings, or a combination of steel castings and rolled steel shapes or plate, united by welding.

How impressive advances in the application of east-weld methods are being employed to effect noteworthy economies and production gains is convincingly shown in practical case-record examples from the files of the Steel Founders' Society of America.

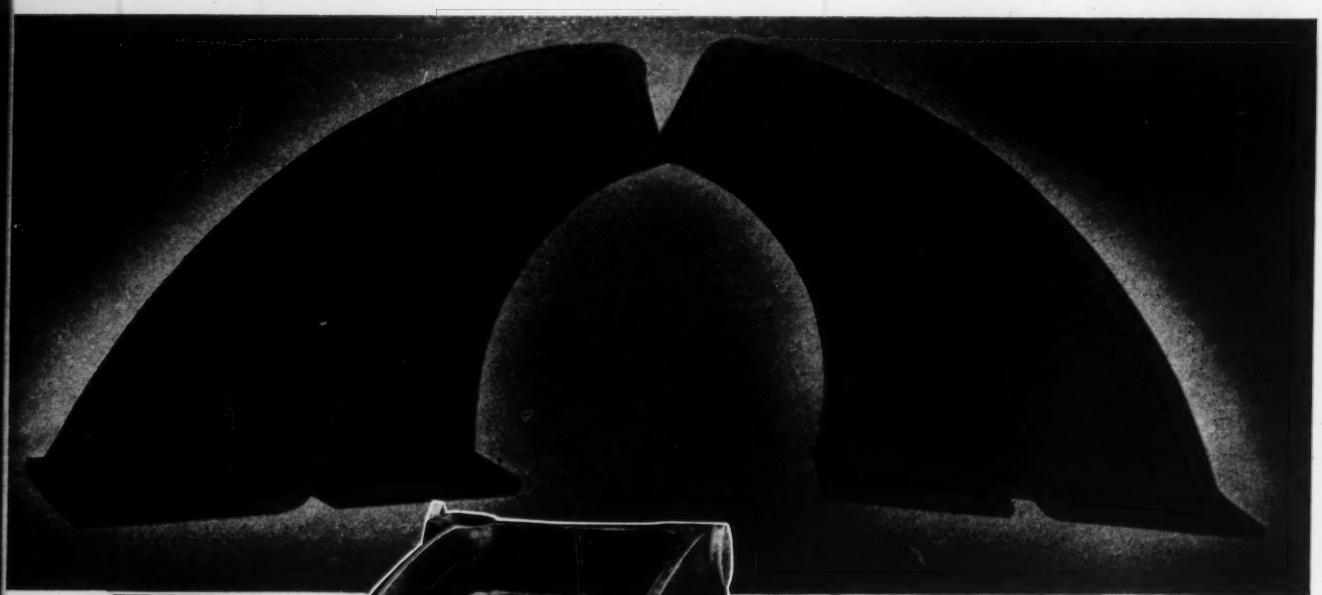
Because of the costs entailed in coring an original one-piece casting design, car builders developed a weldment design for the center filler consisting of 17 parts and requiring 672 lineal inches of welding. A subsequent design, consisting of two cast steel side pieces and a separate center piece, was evolved by Symington-Gould Co. The new three-piece cast-weld

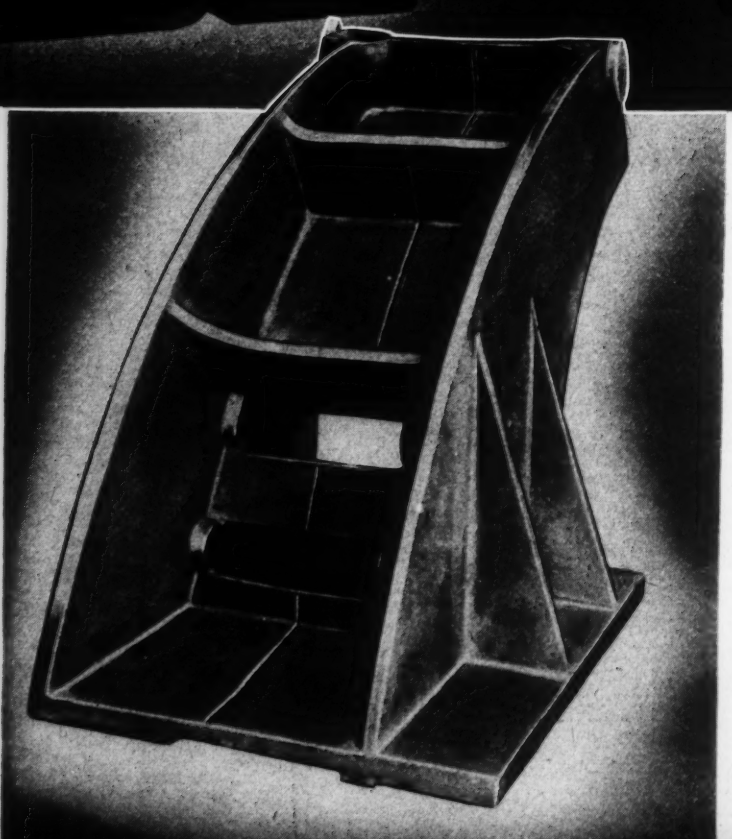


structure enabled a reduction of core weight from 308 pounds to three pounds per casting, resulted in a reduction of 638 lineal inches of weld and a 30 per cent reduction in casting weight. Other gains were in increased daily output of foundry molds, considerable reduction in the cubic content of sand per mold, and reduction in labor handling costs.

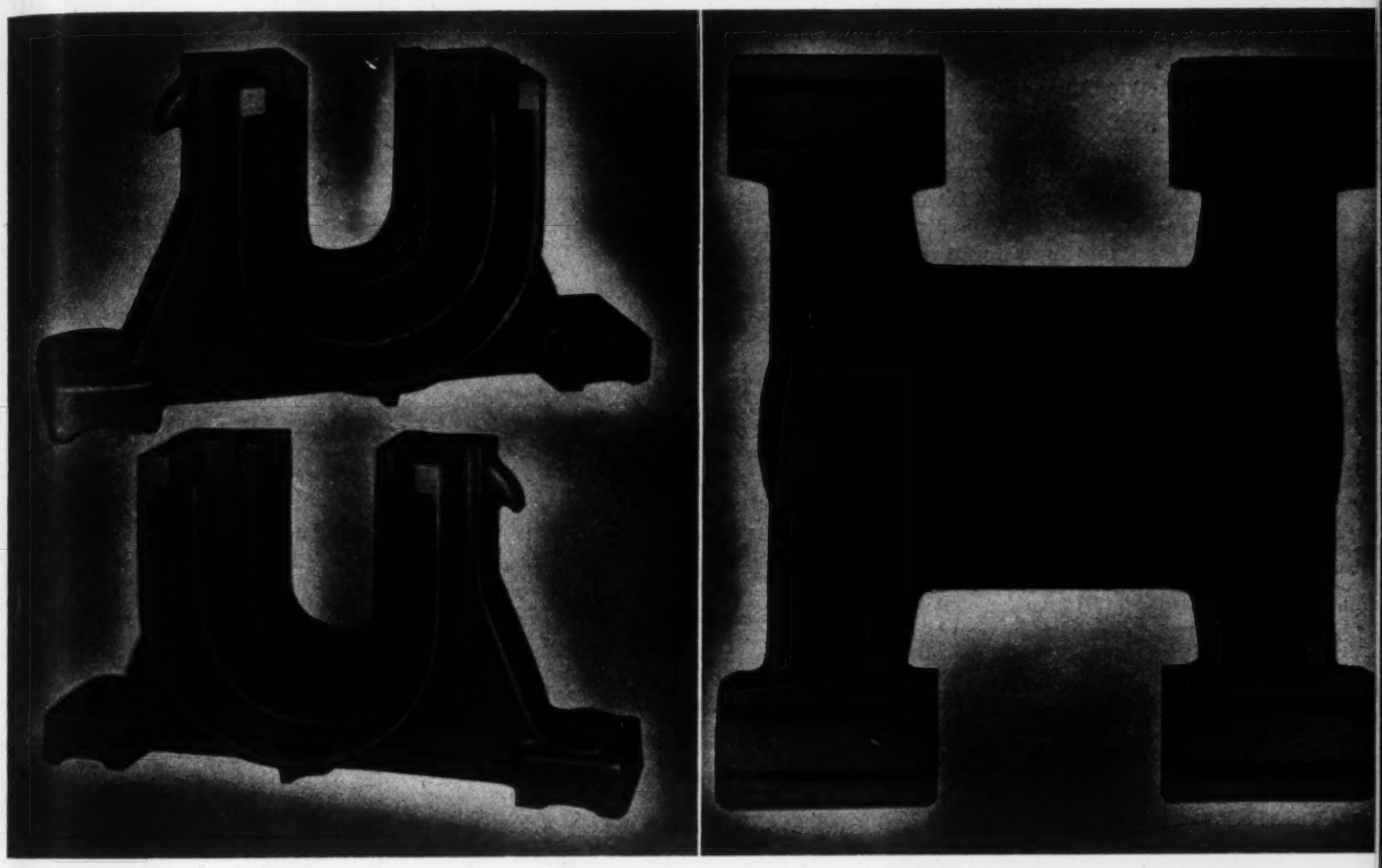
This technique was also applied to a striker casting, the original design for which was a combined striker body and front draft lugs. Here again, reduction of core costs was necessary. Internal cores in the original one-piece striker design weighed 186 pounds. After redesign of the casting to a three-piece welded structure, it was possible to reduce core weight to one pound. Molding costs were reduced in similar degree.

Approximately 20,000 car sets of the cast-weld center filler and striker units have been produced, with complete customer satisfaction as to quality and ease of application. Production cost reflected in selling price has been reduced 25 per cent.



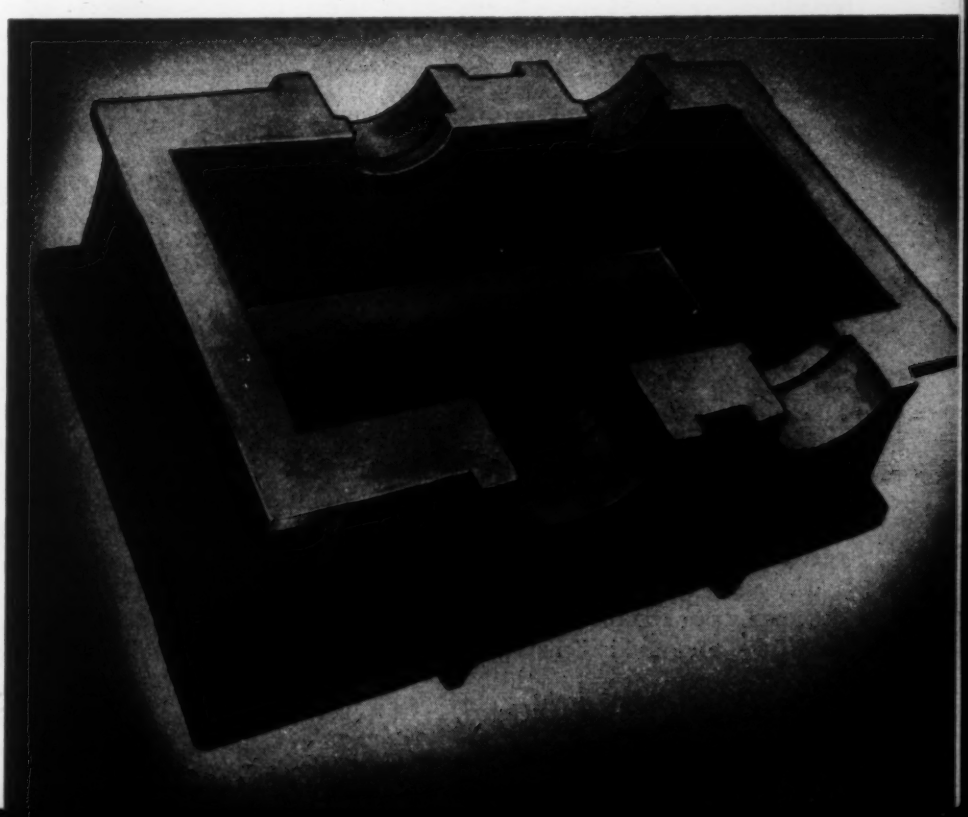


Castings requiring many cores or heavy-cored castings of rangy size can easily be brought into the category of economical castings if they are redesigned to eliminate cores. Pursuing this basic approach, many cases are found in which it is beneficial to redesign to cast-weld construction. These ponderous strip repeater castings, weighing 5000 pounds, were difficult and costly to cast in one piece. By redesigning into two castings to be joined by welding and by eliminating all cores, Birdsboro Steel Foundry and Machine Co. effected an overall saving of approximately 25 per cent. Pattern costs were considerably lower, and the absence of core costs combined to effect an overall manufacturing cost 10 per cent less than that estimated by an outside fabricator.



An order for eight 6170-pound rolling mill pinion housings, frequently made in a one-piece cast design, posed the need for new pattern equipment. By designing the housing as a cast-weld unit as shown, a 15 per cent saving was accomplished by Birdsboro Steel Foundry. Welding two castings to form the required shape necessitated only a half pattern and eliminated the need for a main body core. Pattern cost alone by this method was approximately 30 per cent less than if a full pattern were used.

Minimum production cost for the quantity involved was obtained by cast-weld redesign of this 5000-pound machine drive housing, previously considered less expensive as a fabrication in which steel castings were used only for bearing pads. The two sides are castings and bottom and end pieces are steel plate construction, welded together. In this case, were a 100 per cent casting required, Birdsboro Steel Foundry found that fabrication would be less costly due to the necessarily large center core. However, actual saving with cast-weld construction was about 32 per cent compared to a full casting, and 5 per cent less than was being paid for a complete weldment.



In construction of a 600-pound tripod casting used on coilers for rolling mill machinery, savings of approximately 15 per cent were made by Birdsboro Steel Foundry and Machine Co. By supplanting a fairly intricate one-piece steel casting with four separate castings designed as a cast-weldment, core boxes were not needed and pattern costs were materially lower than for a full casting. The amount of weld was small and comparison of welding time to coremaking and core setting for a full casting proved the advisability of conversion.

Supersonic Tunnel Tests Large-Scale Models

GIANT tunnel installation for studying supersonic flight using a 4 by 4-ft tunnel has been in preliminary operation at Langley Aeronautical Laboratory in Virginia for over a year. Use of test models large enough for installation of extensive instrumentation is possible. A 32-inch span model of a complete supersonic airplane now under investigation is fitted with movable controls and more than 300 pressure orifices.

Key element of the new research unit is a specially designed axial compressor which generates a flow up to 870,000 cfm and is believed to be the most efficient device ever built for the movement of air. It was designed and constructed by Allis-Chalmers in conjunction with NACA Langley engineers. The seven-stage, 11-ft diameter, 1137-blade compressor operates at tunnel pressures from 0.25 to 2.5 times atmospheric pressure and requires up to 60,000 hp to drive it. It circulates air through the test section of the tunnel at velocities ranging from 1.2 to 2.2 times the speed of sound.

The bladed rotor weighs about 65 tons. Tip ends of the rotor blades travel at a speed of around 560 miles an hour when running a maximum speed.

VACUUM METALLIZING

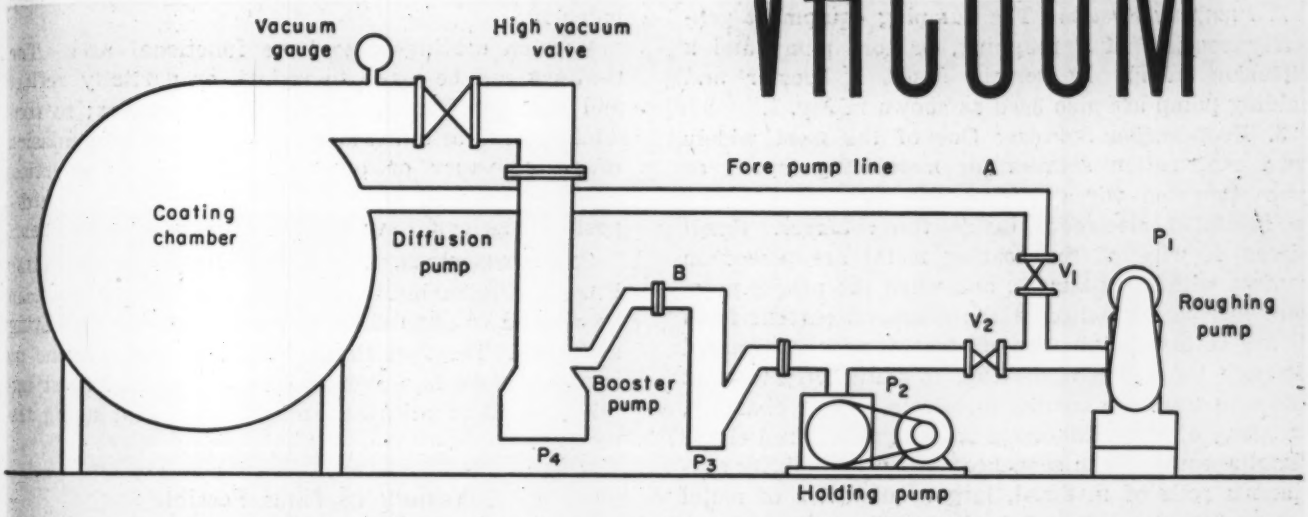


Fig. 1—Typical layout of equipment for vacuum metallizing

Characteristics and applications of evaporated metal coatings

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VACUUM metallizing has developed in recent years into an extremely versatile and economical commercial operation. Although the process has been known for over half a century, it is only since the development of high-speed vacuum pumps and efficient vacuum systems that vacuum coating has become a successful process.

Vacuum coating, in many instances, has supplanted older processes by providing a superior product at lower cost. In other instances, it makes possible new products and applications which were impractical or impossible by other methods.

When a metal or metallic compound is sufficiently heated under conditions of high vacuum, vapor particles radiate from the hot source and deposit on any surfaces they strike. The process consists of exposing the object to be coated to the vapors in such a way that a film of the evaporating material is deposited on the object.

Vacuum coating finds its greatest usefulness in the applications of metallic surfaces, functional or decorative, to materials which are nonconductors of electricity. A partial list of the materials which have been successfully metallized includes glass, metal, paper, plastics, cloth, wax, inorganic crystals, and most lacquered surfaces. Although some of these materials can be metallized by other methods, vacuum coating often produces a superior product at lower cost. In many cases, however, no other method can deposit metallic films with the properties characteristic of evaporated films, and these unique properties make possible products which could not otherwise be made. The list of such products is constantly growing as knowledge of the process becomes more widespread.

EQUIPMENT: As vacuum metallizing equipment has been described in detail in a number of places, and since this article is concerned mainly with applications, only a brief outline will be given. In general, the following equipment is required.

1. *Chamber:* The chamber is an airtight container in which a pressure of 0.5-micron or lower can be maintained by vacuum pumps. Vacuum metallizing chambers vary greatly in size and shape, and in their method of construction. They range in size from a diameter of less than an inch to a diameter of over 17 feet (which is the diameter required for metallizing the 200-inch telescope mirror of the Palomar Ob-

servatory.) Their shape generally consists of a cylinder with dished ends, or of a hemisphere when made of glass. In some cases, the object to be metallized can itself serve as the vacuum chamber, when all or a portion of its inside is to be coated. Examples are spotlight bulbs, sealed-beam headlights, infrared bulbs, and television tubes.

2. *Pumping System:* The pumping equipment generally consists of a roughing, or fore pump and a diffusion pump. In certain cases, a booster and holding pump are also used as shown in *Fig.* 1.

3. *Evaporation Sources:* One of the most widely used evaporation sources for metallizing is one or more tungsten wires twisted together and fastened to insulated electrodes inside the chamber. Small pieces of wire of the coating metal are placed in contact with the filament, and when the proper pressure has been reached in the chamber, current from a low-voltage high-current transformer is passed through the filament, heating it sufficiently to melt and evaporate the coating metal. In a large chamber, an array of many filaments is often used, fired either simultaneously or in sequence. When metallizing continuous rolls of material, larger quantities of metal are used than can be retained on a filament. In these cases, the metal is usually contained in a crucible which is heated to the evaporation temperature by induction or other heating methods. Continuous lengths of material three to five thousand feet long involving the evaporation of several pounds of metal are commercially coated by the use of such sources.

4. *Jigs and Fixtures:* When evaporation takes place in a high vacuum, vapor particles travel in a straight line until they strike the surface on which they deposit. The function of jigs and fixtures is to hold the object so that the surfaces to be coated will intercept the vapor particles from the source. If only one side of an object is to be coated, the objects are placed in stationary jigs arranged around the walls of the chamber with the side to be coated facing the source, as in *Fig.* 2. Where the objects are to be coated on all sides, the objects are placed in jigs which can rotate, exposing all surfaces to the vapor, as in *Fig.* 3. When the object to be coated is a roll of material such as cellulose acetate, cellophane, cloth, or other such material, it is unrolled onto another roll, exposing the surface to be coated during the winding process, as shown in *Fig.* 4.

Coatings Limited by Evaporation

COATING MATERIALS: Most metals, some alloys, and a number of salts have been used as coating materials. Whether or not a particular material is suited to the metallizing process is determined by its internal stability and vapor pressure. The practicability of heating the material to the evaporation temperature is also a limiting factor. The most commonly used metals are aluminum, gold, silver, zinc, chromium, and nickel.

PURPOSE OF VACUUM COATING: Vacuum coating adds new properties to the object coated. These properties can be decorative, functional, or both. In the decorative field, the high metallic luster produced by vacuum metallizing has increased the attractiveness of many products. These metallized coatings are usually covered with transparent colored lacquers and produce decorative effects in a full range of metallic colors. In conjunction with plastics, where the low weight, ease of fabrication, and the possibility of intricate design detail in the plastic is combined with metallic appearance, new markets have been opened to the plastics industry.

Vacuum coatings also have functional uses. The coatings can be made to reflect, or partially reflect and partially transmit light and heat waves; to conduct current, or to act as a barrier to the transmission of water vapor or other gases. These properties, together with the other characteristics of vacuum deposited coatings, have led to many new applications.

CHARACTERISTICS OF VACUUM DEPOSITED METALLIC FILMS: Unlike electroplating, metallic coatings can be applied to nonconductors as well as to conducting materials. The fact that metallizing can be done on nonconductors is a great advantage and in most applications it constitutes a major reason for using the method.

Variety of Films Possible

Thickness and reproducibility of the film can be controlled to one ten-millionth of an inch. Metal films can be deposited so as to be invisible, semitransparent, completely opaque, or any intermediate gradation. An aluminum film opaque to sunlight is about three millionths of an inch thick. Such a film will completely cover the color of the object on which it is deposited, will have an electrical conductivity of about one-half to one ohm per square centimeter, will be an efficient reflector of visible light and of infrared radiation, and will have a moisture vapor transmission of less than 0.5-mg per square inch per 24 hours (ASTM D-988-48T method B, 95 per cent R. H., 100 F). For many purposes, therefore, coatings need not exceed this thickness, and indeed are generally required to be thinner. The following examples show how the properties of such reproducible thin films are used.

Semitransparent Mirrors: In some optical instruments, mirrors are needed which will partially reflect and partially transmit light. These can be reproduced by evaporation. Furthermore, these films can be made of aluminum or chromium to prevent tarnish, and can be protected from abrasion by evaporation of a thin film of silicon monoxide or quartz over the metal.

Nonreflective Coatings: Nonreflective coatings are produced on lenses for cameras, binoculars, and scientific instruments by depositing on the lenses evaporated films of magnesium fluoride about 3×10^{-6} inches thick.

Quartz Crystals: Quartz crystals, carefully ground to vibrate at specified frequencies, are used as frequency controls in electrical oscillators. Films of metal evaporated on the proper faces make good electrical contact with the crystal, yet are so thin that they do not alter its vibration characteristics.

Barrier Layer Photocell: This consists of an electrode on which is deposited a layer of material such as selenium which becomes a conductor of electricity

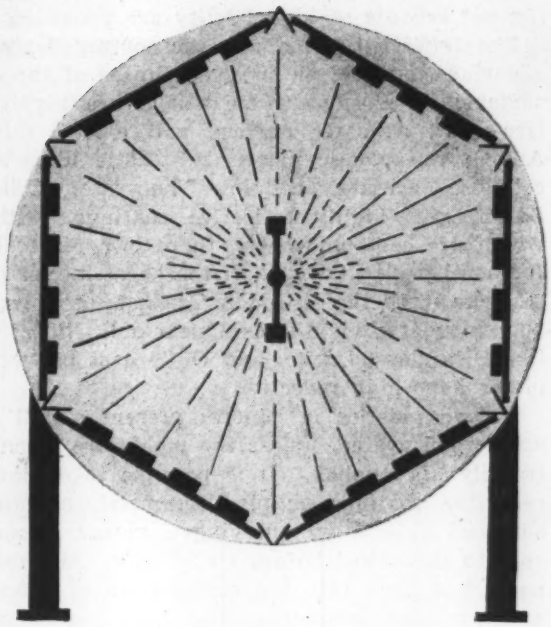


Fig. 2—Vacuum chamber for one side coating

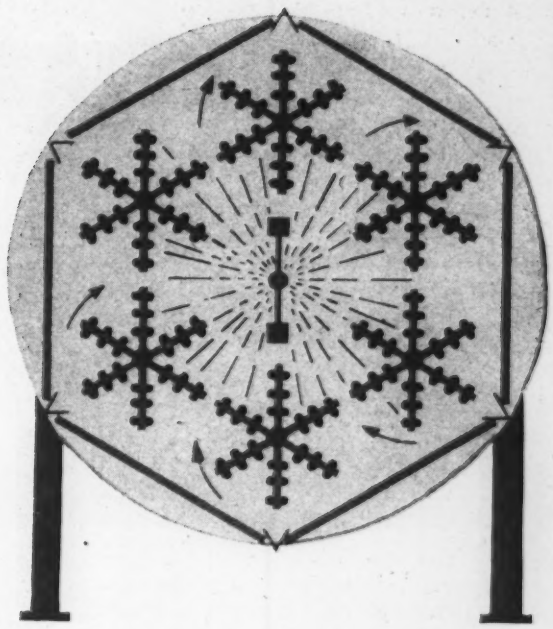


Fig. 3—Chamber layout for complete surface coating

when light strikes it. To complete the electrical circuit, an electrically conducting layer which will allow light to pass through it is deposited over the barrier layer by evaporating on a semitransparent film of cadmium.

Gold Stamping Leaf: This consists of a sheet of acetate or cellophane on which has been deposited a wax layer, a layer of gold, and a layer of thermoplastic adhesive. The thermoplastic adhesive is placed in contact with the object to be stamped, and a hot die brought down on the acetate sheet. The thermoplastic layer adheres to the object and to the gold layer; the layer of wax melts releasing the gold from the plastic carrier sheet; and the sheet is lifted off, leaving a gold impression on the object in the exact shape of the die. For economic reasons, the minimum amount of gold which will give a good gold color is used; this is slightly under three millionths of an inch thick, or about 2.5×10^{-4} ounces troy per square inch. By vacuum evaporation, a gold layer of this thickness is deposited on the nonconducting wax layer. Commercially this is done in a continuous evaporator on acetate rolls over three thousand feet long.

Metallized Condenser Paper: Electrical condensers are defined theoretically in terms of two conducting electrodes separated by a nonconducting dielectric. In one type of practical condenser, the electrodes are long strips of aluminum foil separated by insulating layers of paper. To save space, these are rolled up into a compact bundle. A type of paper condenser which is smaller and lighter than the aluminum foil type for the same capacity can be made by depositing a very thin conductive metal layer directly on the insulating paper. This type has, in addition to size advantages, a property called self-healing. The ordinary foil condenser can be "shorted" and made inoperative by arcing through a weak spot or a conducting particle in the insulating paper. When an arc occurs for the same reasons in a metallized paper condenser, the thin metal layer around the defective spot is volatilized, leaving a nonconductive area, and the short caused by the arc is self-healed by the arc. A metallized paper condenser can withstand thousands of such dielectric breakdowns without change in capacity or effectiveness. The thickness of metal must be rigidly controlled since too thin a layer will result in a condenser of high resistance, and too thick a layer will not give good self-healing properties. Metallized condenser paper is made by evaporating zinc or aluminum on continuous rolls of special 0.0003-inch thick paper.

Film Thickness Limited

Although generally advantageous, the thinness of the deposited films also creates some problems. It takes more than three hundred times the amount normally evaporated to build up a film even one thousandth of an inch thick, should that be required. A vacuum deposit can, however, be used as a conductive base for electroplating, and is so used in a number of applications. The films have poor abrasion resistance, and in any application where there is abrasion the films require a protective coat. This is not a complete disadvantage, since by the application of transparent colored lacquers a practically unlimited range of metallic colors is made possible. Where the exposed surface must be conducting, lacquering is of course not permissible.

Coatings which are deposited on clean surfaces have good adhesion. The degree of adhesion depends on the nature of the coated material but on many materials, even without special surface preparation,

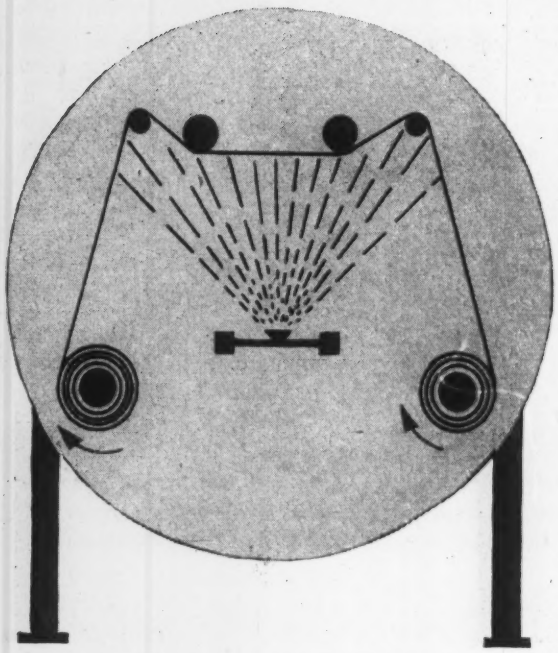


Fig. 4—Vacuum metallizing setup for continuous roll coating of long strips

the adhesion of the evaporated coating is great enough so that it will not be lifted off by Scotch tape. Special surface coatings have been developed which increase the adhesion of evaporated films.

Poor adhesion may result when the material to be coated is oily, or outgases during the coating operation, or when the evaporation is done at too high a pressure. In the latter case, the appearance of the metallic film is discolored and dull.

Evaporated films have great flexibility, and practically no film strength. The films will not chip or crack. Consider for example, soft vinyl sheeting on which a shiny metallic film has been deposited. Bending and flexing the sheet has no effect on the film. If the sheet is stretched, the film appears to stretch with it, with no loss of flexibility or adhesion. The film, however, will lose its high metallic luster and appear dull. The high luster reappears if the tension is released and the sheet recovers its original form.

Under proper conditions of vacuum, each molecule evaporating from the source will travel independently in a direct line to the object and condense on the surface. A thin film built up in this way reproduces the surface of the object with great fidelity. So high is the fidelity of reproduction, that replicas of a surface made by evaporating a thin film of quartz on a specimen are often used for study in electron microscopes instead of the specimen itself. The replica technique is used when the specimen undergoes changes under the action of the electron beam in the microscope.

Record masters are coated with a thin, uniform, gold coating which exactly reproduces all the detail of the sound track. This coating serves as a conductive base for electroplating a heavy coating of metal. In this way, an electroformed die for stamping out records of high fidelity are produced.

The reflectivity of a metallic coating deposited on a surface depends on the smoothness of the original surface. A glossy surface will give a highly reflective coat, a matte surface will give a dull coat. Among the plastic materials, plastic films such as cellulose acetate, cellulose butyrate, Cellophane, Saran, give highly reflective coatings. With films which are cast on wheels, there is a noticeable difference between the side of the sheet in contact with the wheel and the air side. Coatings on polyethylene and calendered vinyl films appear dull. Sheet plastics like Plexiglass, Lucite, and CR39 cast between glass plates have high reflectivity.

Molded plastics in general present a dull appearance when coated, unless the molds are given an extremely high polish. It is possible to obtain highly reflective coatings on plastics, metal, or other dull surfaced objects by applying a glossy lacquer base coat to the object before metallizing. Much development has gone into the formulation of proper base and top coat lacquers. The base coat must have good adhesion, high gloss, contain no materials which will outgas in vacuum, and resist softening or lifting by plasticizer migration from the plastic or solvent action from the protective lacquer top coat over the metallized film. The top coat lacquer must have good abrasion resistance, have good adhesion to the metal film, be capable of being colored by incorporating dye or by dip dyeing, and should contain no solvents which will cause swelling or crazing of the base coat because this will adversely affect the appearance of the metallic film. Combinations of base coat and top coat lacquers have been worked out for almost all of the plastic compositions.

Low Vacuum Dulls Film

In order to deposit a bright, adherent metal film from the vapor phase, a high vacuum is essential. High vacuum, however, is a relative thing which depends on the dimensions of the equipment. In general, for the purpose of vacuum evaporation, vacuum is high when the molecules of evaporated metal leave the source and deposit on the object without making any collisions with residual air molecules. If the pressure is too high, the resultant film will appear discolored, dull and will lack adhesion, and in some cases, the back of the object will be coated with metal particles reflected back from collisions with gas molecules.

SELECTIVE COATINGS: Articles can be metallized with only selected areas coated. Coatings in patterns, designs, or letters can be made either by preventing the evaporated metal from depositing on selected areas, or by removing the metal film from these areas after the object is completely coated. Both methods have been used successfully in batch and continuous coating. One of the most practical methods for preventing the metal from depositing is to mask the area to be left uncoated. The mask can be a resin coating, masking tape, or a metal mask in contact with or close to the piece so that it throws a

(*Continued on Page* 180)

DESIGN ABSTRACTS

Molded Nylon Gears

By Fred R. Zumstein
Fellows Gear Shaper Co.
Springfield, Vt.

NEW TYPES of thermoplastic materials now available can be considered for gears. The gear industry has long been familiar with thermosetting plastics in the form of laminated and certain cotton-filled phenol-formaldehyde materials in silent gearing. The latest production methods with thermoplastic materials show considerable cost savings by injection molding with fast cycles in permanent steel molds.

PLASTIC MATERIALS: Recent improvements by material manufacturers have centered on higher heat resistance. Commercial polystyrene plastic materials have shown much improvement along these lines. These materials are also outstanding for their dimensional consistency. This stability over a wide humidity change not only makes them outstanding among thermoplastics, but also allows them to compete with phenolics in spite of a slight material-cost disadvantage.

Heat-resistant (180 F) cellulose acetate materials have been recommended for small precision parts since unexpectedly favorable test results have been reported by several manufacturers. Further investigation seems to be justified because of low manufacturing costs by injection molding.

A majority of thermoplastic gear applications today appear to favor the use of polyamide materials, more commonly called nylon. Possessing the highest heat resistance among the lower-priced thermoplastic materials, nylon dominates in these applications. Materials with even higher heat resistance are available, including a trifluoro-chloro-ethylene at approximately $14.00 per pound.

DESIGN CONSIDERATIONS: In less-rigid thermoplastic gears, such as nylon, resiliency absorbs the inevitable inaccuracies of cut gears. The self-lubricating characteristic utilized in plain nylon bearings in textile equipment is also favorable for offsetting friction of mating gear-tooth surfaces.

The Massachusetts Institute of Technology has conducted a series of tests on nonmetallic gears and has worked out a velocity factor in recognition of the low specific gravity of such materials as nylon and laminated phenolic gears.

For nonmetallic materials

$$K = \frac{150}{200 + v} + 0.25$$

whereas for commercial quality metallic gears

$$K = \frac{600}{600 + v}$$

where K = velocity factor and v = pitch-line velocity, fpm. With pitch-line velocities greater than 1000 feet per minute, the velocity factor for plastic gears will be higher than that for metallic gears.

Safe working stress is the product of safe static stress and velocity factor. According to Du Pont, nylon has a tensile strength at room temperature of 10,530 psi. Tests on Nylon FM-10001, show flexural fatigue strength of 6000 psi.

The following table notes safe working stresses at varying pitch-line velocities using the above formula for nonmetallic materials and the conservative 6000 psi as a static stress factor for nylon:

Pitch-Line Velocity (fpm)	Safe Working Stress (psi)	Pitch-Line Velocity (fpm)	Safe Working Stress (psi)
100	4500	1000	2250
150	4071	1500	2029
200	3750	2000	1909
250	3500	2500	1833
400	3000	3000	1781
500	2786	4000	1715
800	2400		

Theoretically, plastic and steel gears deflect similar amounts when sub-

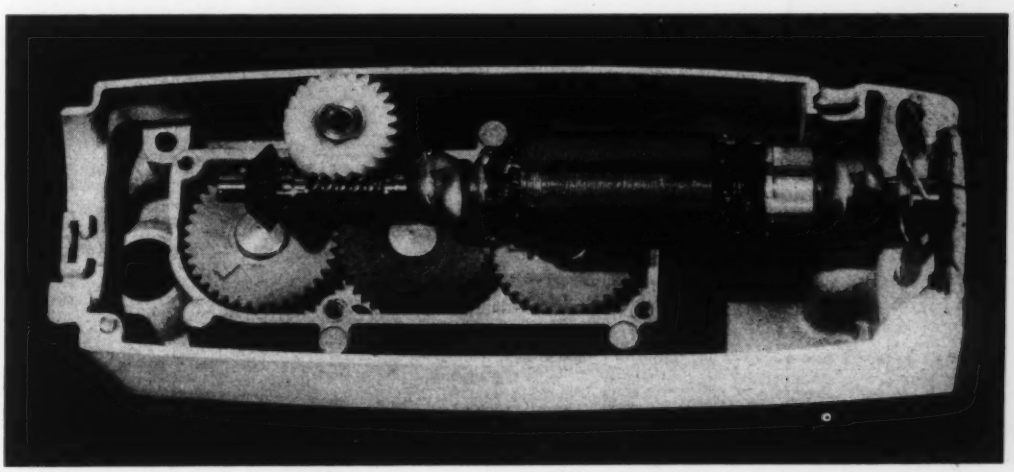


Fig. 1 — Three food-mixer beaters are driven by a phenolic and two sintered-iron gears, which are in turn driven by a molded nylon helical gear

jected to loads proportional to their moduli of elasticity. Horsepower loads based on the strength of a single tooth can be determined from the Lewis formula using the foregoing stresses for plastic. Rigid metal gears with slight inaccuracies of tooth form and spacing may create high dynamic loads which have to be carried by a single tooth. The resiliency of nylon plastic, however, may allow contact of two or more teeth under load conditions. Consequently, computations will be conservative.

Tooth wear on plastic gears is affected by relative sliding of gear tooth surfaces, excessive compressive stress at progressive points of contact, and cutting of the flank of the driving tooth by the tip of the entering tooth. A nylon driving pinion mated with a steel gear can be relieved of undue wear by adoption of the all-addendum form on the pinion, thus reducing the angle of approach and eliminating the trochoidal path of the tip of the entering driven tooth. Tooth strength is thereby increased 50 to 75 per cent. This procedure is more desirable than modifying the tip of the steel driven-gear tooth, which would reduce tooth-contact duration and would not remove tendency to interfere. When plastic is used for driven gears, these modifications are necessary only to eliminate excessive undercut.

One factor currently being studied is the low heat conductivity in nylon gears. Experimental gears have been made with copper shims to facilitate conduction of heat from the gear tooth area to prevent undue wear and deformation from heat generated at this point. In more critical cases of gear design where the favorable silent-wear characteristics of nylon may be desired, a gear blank or insert could be used in the mold with a thin cross-section of plastic molded over the surface of the insert. The problem of heat dissipation can then be minimized while increasing the beam strength with a metal insert.

APPLICATIONS: Shown in *Fig.* 1 is a plastic gear application in a food mixer. This General Electric mixer assembly includes a nylon gear mounted on a steel shaft. The pinion drives three beaters through one phenolic and two sintered-iron gears. This unit can be loaded to a stopped-motor condition without damage to the nylon gear. A complete plastic pinion and gear assembly will be considered after field tests.

In the field of cameras and projectors, nylon gear applications have been extensive for two reasons: the silent-operating, self-lubricating characteristics, and the cost savings by injection molding a complete cluster or original assembly of separate parts.

A set of gears used in the RCA 16-mm projector are injection molded at one-third the previous cost. This application with no lubrication gives three times the wear life of steel gears.

Small nylon gears are used in cash registers and calculating machines by the National Cash Register Co. In spite of a plastic-material volumetric cost approximately ten per cent mor than steel, one plastic pinion wa produced at one-tenth the cost of th original steel fabrication.

Current and pending automotiv applications of nylon gears includ worm and pinion parts for a governo drive. A nylon-with-nylon combina tion is showing satisfactory results and at this writing 65,000 miles hav been accumulated on a dry test setup. A nylon worm with steel pinion also has shown satisfactory performance. In this case the steel pinion must be hardened (approximately 400 Brinell) and polished. A brass worm and nylon pinion combination were the most unsatisfactory. Brass apparently has some affinity for nylon, even though highly polished, and tends to cause more wear. A similar test run at National Cash Register Co. on nylon with aluminum spur gears showed severe abrasion on both nylon and aluminum gear surfaces.

From a paper entitled "New Plastic Material for Non-Metallic Gears," presented at the 35th Annual Meeting of the American Gear Manufacturers Association in Hot Springs, Va., June 4-6, 1951.

Powder-Metal Gears

By D. W. Lynch, T. J. Snodgrass and T. T. Woodson

Construction Materials Dept., General Electric Co.
Bridgeport, Conn.

WITHIN the last decade powder metals have begun to compete in the structural parts field, a field in which they must compete primarily on a cost basis. This paper concerns General Electric's experience in a segment of that field—powder-metal gears.

APPLICATION: Powder-metal gears used in the General Electric appliances shown are of two types of sintered-iron material. The first is standard sintered-iron alloy with a 35,000 psi tensile strength. The second is copper-impregnated sintered

(*Continued on Page* 184)

Table 1—Limiting Tolerances for Gear Manufacturing Processes

Process	Degree of Care*	Tooth to Tooth Spacing (in.)	Concentricity (TIR, in.)	Profile (Inv. var., in.)	Helix (in.)	Composite Check (Total tooth error, in.)	Tooth Thickness (in.)	Tooth Surface Finish (rms microinches)
Sintering—*Assumed size of part:* 0-1½ *diam,* 0-¾ *face width,* 10-32 *DP.*								
	Commercial	0.0007	0.0025	0.0005	0.0007	0.003	0.001	45
Sintering—*Assumed size of part:* 1½-4 *diam,* 0-1 *face width,* 10-20 *DP.*								
	Commercial	0.001	0.004	0.001	0.0007	0.004	0.002	45
Stamping—*Assumed size of part:* 0-1 *diam,* 0-$\frac{1}{8}$ *face width,* 20-128 *DP.*								
	Commercial	0.001	0.003	0.001	0.0005	0.004	0.001	128
Extruding—*Assumed size of part:* 0-½ *diam,* 0-¼ *face width,* 20-128 *DP.*								
	Commercial	0.001	0.005	0.002	0.001	0.007	0.001	64
Hobbing—*Assumed size of part:* 0-6 *diam,* 0-1 *face width,* 20-126 *DP.*								
	Commercial	0.0005	0.003	0.001	0.001	0.0035	0.002	63
	Precision	0.0003	0.002	0.0006	0.0005	0.0025	0.001	32
	Very best	0.0002	0.001	0.0004	0.0003	0.0012	0.0005	16
Grinding—*Assumed size of part:* 0-8 *diam,* 0-1 *face width,* 8-64 *DP.*								
	Commercial	0.0005	0.002	0.0010	0.0005	0.0025	0.0015	40
	Precision	0.0003	0.0012	0.0004	0.0003	0.0015	0.001	25
	Very best	0.0002	0.0006	0.0003	0.0001	0.0010	0.0003	10

* Commercial—Quality obtainable in good job shops. Precision—Quality obtainable with new or first class machine tools and precision tooling. Very best—Quality at 25 to 50 per cent extra cost with best tools and personnel

NEW PARTS AND MATERIALS

. . . presented in quick-reference data sheet form for the convenience of the reader. For additional information on these new developments, see Page 161

MINIATURE BALL BEARING 1

. . . has low starting torque

New Hampshire Ball Bearings Inc., 12 Micro Circle, Peterborough, N. H.

Low and uniform values of starting or breakaway torque are characteristic of this miniature ball bearing.

Size: $\frac{5}{16}$-in. OD, $\frac{3}{32}$-in. bore, $\frac{7}{64}$-in. wide; tolerance, ABEC-5 or higher.

Service: Low, uniform starting or breakaway torque, most values falling in range 0 to 0.0006 oz-in. with 75 gm thrust load.

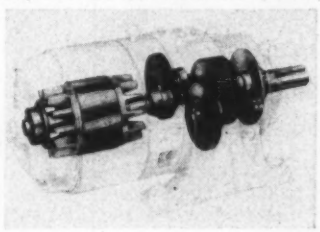
Design: Stainless-steel coil-spring separators; high-carbon chrome-steel or stainless-steel rings and balls.

For more data circle MD 1, Page 161

TWIN-PINION GEARMOTORS 2

. . . have twice normal torque ratings

U. S. Electrical Motors Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.



Since two secondary pinions drive the output gear, torque ratings are doubled without increasing external dimensions.

Designation: GL, GM.

Size: GL, 5 to 25 hp; GM, 1 to 10 hp.

Service: GL, ratios to 45:1, speeds from 30 to 84 rpm; GM, ratios to 175:1, speeds from 5 to 25 rpm; torque ratings are double for same-size single-pinion unit, splined herringbone primary pinion is free to slide to balanced position, giving equal torque distribution through twin pinions; gear compartment sealed against dust and dirt.

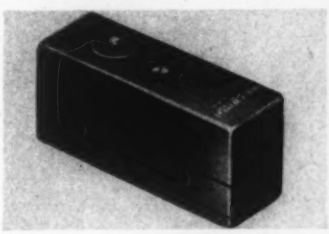
Design: Twin-pinion; GL, double reduction; GM, triple reduction; herringbone gears hardened to 45/50 Rockwell; ball or roller bearings; sealed oil reservoir; asbestos-protected windings; castings normalized; centrifugally cast rotor.

For more data circle MD 2, Page 161

SNAP-ACTION SWITCH 3

. . . for direct-current applications

Mu-Switch Div., Acro Mfg. Co., Canton, Mass.



An Alnico magnet in this precision switch blows out the arc to prevent burning as soon as contacts open or close.

Designation: TB-5000.

Size: $1\frac{15}{16}$ in. long, $\frac{11}{16}$-in. wide, $\frac{31}{32}$-in. high.

Service: Rated 10 amp at 125 v d-c, 5 amp at 230 v d-c.

Design: Precision, snap-action; single-pole, double-throw; Alnico-magnet arc blowout; melamine base and cover, metal available; pin, leaf or plunger actuators available; No. 8 screw terminals; interchangeable with Mu snap-action a-c switches.

For more data circle MD 3, Page 161

CONVEYOR CHAIN 4

. . . is totally enclosed

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.

This flat-top conveyor chain can curve around corners with six-inch radii, minimizing the number of transfer points and power sources needed.

Designation: Rex FlexTop.

Size: Top plates, $3\frac{1}{2}$ in. long, $3\frac{1}{4}$ in. wide, pitch approx. $1\frac{1}{2}$ in.; sprockets with 12, 14, 16, 18, 20, 24, 28, 32 pitches, 5.796 to 15.303 in. PD, respectively; idler wheels, 14 in. diam.

Service: Max. working load, 800 lb; average ultimate strength, 4800 lb; min. flexing radius 6 in.

Design: Carbon or stainless-steel top plates induction-welded to links; links connected by universal joint; cast-iron sprockets and idler wheels.

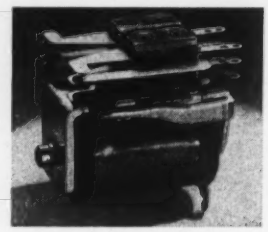
Application: Conveyors on bottling, wrapping, labeling, filling machinery.

For more data circle MD 4, Page 161

SMALL RELAY 5

. . . utilizes telephone type construction

C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30, Ill.



With a telephone-type reed armature suspension, these d-c relays are similar to the Clare type K, but have improved sensitivity, operating range and life.

Designation: Type R.

Size: $1\frac{31}{64}$ in. long, 1 in. wide, height $1\frac{5}{16}$ in. min to $1\frac{25}{32}$ in. max; weight approx. $2\frac{1}{4}$-$2\frac{1}{2}$ oz.

Service: Voltage, 230 v d-c; contact pressure, 30 gm standard; hipot test, 1000 v rms.

Design: Reed armature suspension; single or double arm, with 2 to 10 contact springs in each pileup; coil spool has approx. 90% more winding turns than Clare type K; single or double-wound coils; double-wound coils have 4 terminals; can be provided with copper core sleeve or copper slugs on heel or armature end; hermetically sealed relays and various contact materials available.

For more data circle MD 5, Page 161

LEATHER V-BELT 6

. . . double-faced for long life

Graton & Knight Co., 320 Franklin St., Worcester 4, Mass.

This leather, link-constructed V-belt has two opposite V faces, so that it can be used on serpentine drives, or can be turned over on straight drives to provide additional face life.

Size and Service: For linear speeds to 3500 fpm;

Belt Size (letter—width, in.)		Horsepower (at 1000 fpm, 180 deg contact)	Pulley OD (min., in.)	Pitch Length (average, in.)
A	½	0.9	3½	$1\frac{5}{32}$
B	$\frac{21}{32}$	1.2	4	$1\frac{5}{32}$
B1	$\frac{5}{8}$	1.4	4	$1\frac{11}{32}$
C	¾	3.0	6	$1\frac{1}{2}$
C1	⅞	3.2	6	$1\frac{1}{2}$
D	$1\frac{1}{8}$	5.4	8	2

Design: Two fiber sections faced with oak-tanned leather; leather segments are V-beveled to provide double V faces; steel connectors.

Application: Textile, woodworking, printing, pulp and paper, laundry, flour and feed-mill, cotton-ginning, coal-mining machinery; fans, blowers, pumps; machine tools.

For more data circle MD 6, Page 161

PACKING RINGS 7

. . . automatically positioned in stuffing box

Johns-Manville, 22 E. 40th St., New York 16, N. Y.

Sealing lips are positioned diametrically and axially by the center section of the packing ring.

Designation: Uneepac.

Size: ⅝-in. ID to 63 in. OD.

Service: Sealing water, steam, oil, air, gas, vacuum according to composition used; header or follower rings not needed on most applications; each sealing lip is exposed to fluid pressure; sealing does not depend on gland pressure.

Design: Endless or split; two types, for flange widths under and over ½-in.; each ring centers on preceding ring; lips are protected by projecting center section, are supported by succeeding ring; one or more rings can be reversed for alternate pressure and vacuum.

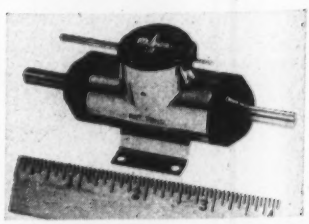
Application: Hydraulic presses, pumps, compressors.

For more data circle MD 7, Page 161

MINIATURE SPEED CHANGER 8

. . . has push-rod adjustment

Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.



Remote control through simple linkage arrangements can easily be applied to this speed changer, because of the straight-line motion of the push rod.

Designation: 4C.

Size: $4\frac{5}{16}$ in. long, $1\frac{1}{2}$ in. wide, $1\frac{37}{64}$ in. high; push-rod diam 0.110-in., travel, 0.375-in.; weight 5.5 oz.

Service: Infinitely variable speed-changing over 36:1 ratio—1/6 to 6 times input speed; 72 oz-in. torque; 0.025 max hp, nominal; max speed (either shaft), 20,000 rpm, either direction; max control-adjustment pressure required, 6 lb; nominal slip, 9%.

Design: Input and output drive disks make contact through two rollers, pivoted to contact disks at changeable radii; input and output shaft rotate in opposite directions; rolling surfaces, hardened ball-bearing steel; permanently lubricated ball bearings; settings can be changed while running or stationary; ratio indicator.

Application: Timers, recorders, controllers, computers, indicating mechanisms.

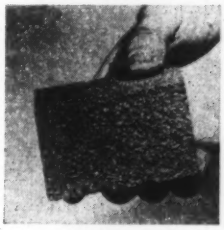
For more data circle MD 8, Page 161

NEW PARTS AND MATERIALS

PHENOLIC RESIN 9

. . . foams to form high-strength cores

Rezolin Inc., 4825 W. Jefferson Blvd., Los Angeles 16, Calif.



Mixed at room temperature, this liquid phenolic resin foams to a hard, cellular core material with high compressive strength.

Designation: Corfoam.

Form: Liquid; hard cellular material after mixing.

Service: Core material with compressive strength of 500 psi; can be foamed in large masses without loss of cell control or undue shrinkage; good heat insulating characteristics and adhesion to wood, paper and most plastics; will not support combustion; low moisture absorption; mixed at room temperature.

Properties: Foams to hard, honeycomb mass with globular, nonconnecting cells; density, 14 lb per cu ft.

For more data circle MD 9, Page 161

TRANSPARENT COATING 10

. . . for polished and plated metals

Adhesives and Coatings Div., Minnesota Mining & Mfg. Co., 411 Piquette Ave., Detroit 2, Mich.

This transparent coating maintains the luster of the metal and protects against tarnishing and corrosion caused by weather.

Designation: EC-1111, EC-1139.

Form: Liquid containing 25% synthetic-resin solids by weight, xylene solvent.

Service: Withstands corrosive action of humidity, industrial smog, road salts; salt-spray resistance, 350 hr with 20% NaCl solution at 100F; weather resistance (accelerated test), 350 hr with cycle of 100 hr sunshine, 20 min water spray; solvents will not attack automotive lacquers and enamels; EC-1111 for brush, EC-1139 for spray application.

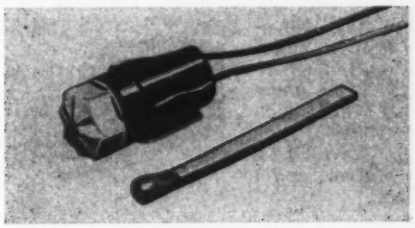
Properties: Viscosity 25-30 sec at 80F with ⅛-in. orifice Ford cup; color-stable; drying time EC-1111—12 min tack-free, 48 hr full hardness, EC-1139—5 min tack-free, 30 min forced drying at 275F; TOC flash point, 92F.

For more data circle MD 10, Page 161

MINIATURE INDICATOR LIGHTS 11

. . . for close mounting on panel

Alden Products Co., 117 N. Main St., Brockton 64, Mass.



These compact 6-volt lights can be mounted 900 to the square foot.

Designation: 86L.

Size: ¾-in. long, 0.348-in. diam.

Service: For 6 v current; crystal-shaped lens permits viewing from any angle.

Design: Pushes into 0.348-in. diam hole; centers can be as close as 0.400-in.; bulb removed by unscrewing lens; leads furnished to length required.

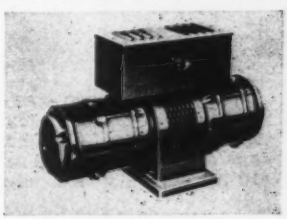
For more data circle MD 11, Page 161

ADJUSTABLE-SPEED DRIVE 12

. . . incorporates dynamic braking

Baldor Electric Co., 4353 Duncan Ave., St. Louis 10, Mo.

Consisting of a drive motor, controller, and motor-generator set, this adjustable-speed drive provides 16 forward and 16 reverse speeds, with inherent dynamic braking.



Size and Service: ¾, 1, 1½, 2, 3 hp, 3-phase; ¾, 1, 1½ hp single-phase; speeds from 0 to 2400 rpm, forward or reverse in 150-rpm steps; vernier adjustment with slide-wire rheostat possible; inherent dynamic braking.

Design: Step-type rheostat controls mg set (shown) and drive motor; excitation by full-wave Tungar-bulb rectifier; glass insulation where practical; prelubricated self-sealed bearings; general-purpose totally enclosed housings.

Application: Bottling, printing, packaging, coiling, brick machines; conveyors; bread wrappers; punch presses; die sinkers.

For more data circle MD 12, Page 161

PILOT-OPERATED VALVE 13

. . . uses line pressure to move spool

Denison Engineering Co., 1160 *Dublin Rd., Columbus* 16, *O.*

Spool-sticking is prevented by using line hydraulic pressure to move the 4-way-valve spool. Solenoids operate small internal pilot valves which control spool movement.

Size: ¾ or 1½-in. pipe.

Service: Pressures to 5000 psi; capacity, 20 gpm at 20 fps; spool moves at same rate of speed regardless of operating pressure; solenoid current (max. inrush), 6.3 amp at 110 v, 3.1 amp at 220 v, 1.5 amp at 440 v; holding current 0.5, 0.25 and 0.12 amp, respectively; 50-60 cycle a-c; spool automatically pressure-centered when solenoids de-energized; mounts in any position; meets JIC standards.

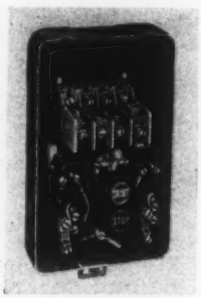
Design: Four-way single or double solenoids and ball-seat pilot valves; single available in 2 porting combinations, double in 8; external pilot-pressure and drain provisions available; left or right-hand solenoid assembly on single model.

For more data circle MD 13, Page 161

MAGNETIC STARTER 14

. . . available in "in-between" size

Furnas Electric Co., 1045 *McKee St., Batavia, Ill.*



These in-between-size starters are designed to replace larger 25-hp starters (NEMA size 2) on applications where only a 10-hp capacity is needed.

Designation: YE series.

Size and Service: 25, 50, 60 cycles.

Voltage	Maximum Horsepower		
	Single phase	2, 3 phase, 3 wire	2 phase, 4 wire
110	2	3	3
220	5	10	10
440–550	5	10	10

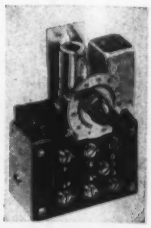
Design: Replaceable rectangular silver contacts; alkyd arc-resistant terminal boards; thermal overload relays of solder-pot type; start-stop pushbuttons, hand-off-automatic selector switch or 3-wire pilot control; general-purpose, weatherproof (water and dust-tight) or open enclosure; dual-voltage coils; package auxiliary switches for interlocks or additional circuits available.

For more data circle MD 14, Page 161

ELECTRONIC RELAY 15

. . . sensitive to low energy pulses

Farmer Electric Co., 21 *Mossfield Rd., Waban* 68, *Mass.*



Operating on a contact closure of extremely short duration, the relay will actuate even if contact resistance is high.

Designation: CK.

Size: 3⅞ in. wide, 4⅞ in. high, 3 in. deep.

Service: Relay actuation on 0.5-millisec pulses through up to 0.5-megohm contact resistance; relay operates 10 millisec after receiving pulse, remains energized for 0.25 to 1.5 sec, adjustable; relay rating, 2 amp, 115 v a-c, noninductive; input, 105-125 v, 60 cycles; neon extinguishing tube opens relay—if removed, relay locks in and remains energized until power circuit is opened; actuating-switch contacts are electrically independent through use of isolation transformer.

Design: Initiating contacts actuate a cold-cathode gaseous trigger-tube operating on d-c from integral selenium rectifier and filter; trigger-tube is extinguished by neon glow lamp after preset time delay; by connecting 2 megohm potentiometer between actuating-switch terminals, relay becomes on-off timer.

Application: Textile-finishing machinery; gaging, sorting, counting and testing devices.

For more data circle MD 15, Page 161

CERAMIC MATERIAL 16

. . . withstands extreme thermal shock

Stupakoff Ceramic & Mfg. Co., Latrobe, Pa.

Available in two forms for high-temperature service, this ceramic has near-zero thermal expansion.

Designation: Stupalith A-2417, A-2209.

Form: Press-molding powder.

Service: High-temperature service as parts, containers, insulators, liners; A-2417 withstands thermal shock test of 2300 F to cold water, can be held at 2000 F for 120 days without change in specific gravity; A-2209 withstands 900 F to cold water test; grade L-3, JAN I-10.

Properties: Coefficient thermal expansion (20-500 C, in. per in. per deg C), 0.063 x 10^{-6} and 0.85 x 10^{-6}, A-2417 and 2209 respectively; compressive strength (psi), 19,880 and 60,800; impact strength (ft lb per $in.^2$), 0.90 and 1.40; modulus of rupture (psi), 4250 and 8000; moisture absorption (%), 21.5 and 0.00; bulk density (gm per cc), 1.60 and 2.34; power factor (both ceramics), 0.492% wet, 0.424% dry; dielectric constant, 5.56 wet, 5.57 dry; loss factor, 0.0273% wet, 0.0236% dry; dielectric strength, 450.0 v per mil.

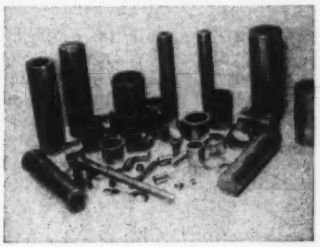
Application: Turbine blades, jet turbines, combustion engine parts and nozzle inserts, jet engine exhaust liners, electric and electronic insulation.

For more data circle MD 16, Page 161

POROUS BRONZE BEARINGS 17

. . . available in new sizes

Boston Gear Works, 64 Hayward St., Quincy 71, Mass.



Adding to their line of oil-impregnated porous bronze bearings, this company has recently announced the addition of 157 new stock sizes in plain sleeve bearings, cored and solid bar stock.

Designation: Bost-Bronz.

Size: Plain sleeve bearings (147 new sizes), 0.127 to 2.4415 in. ID, 0.252 to 3.005 OD; cored bar stock (3 new sizes), 3 to 3¾ in. ID, 5 to 8 in. OD; solid bar stock (7 new sizes), ¼ to 8 in. OD, 2 to 6½ in. long.

Service: Prelubricated; static loads, 8500 psi of projected bearing area (length x ID); operating loads as follows;

Shaft Velocity (fpm)	Load (psi)	Shaft Velocity (fpm)	Load (psi)
slow, intermittent	4000	100-150	500
25	2000	150-200	250
50-100	500	over 200	$\frac{50{,}000^*}{V}$

*Where V=shaft velocity, fpm.

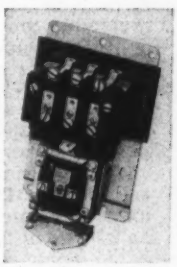
Design: Porous, oil-impregnated bronze.

For more data circle MD 17, Page 161

SOLENOID CONTACTOR 18

. . . convertible from normally closed to open

Ward Leonard Electric Co., 115 MacQueston Pkwy. S., Mt. Vernon, N. Y.



Available in 3 or 5-pole construction, this solenoid contactor can be changed from normally-open to normally-closed operation by inverting moving and stationary contacts.

Designation: Bulletin 4458.

Size: 3-pole (size 0), 6⅝ in. high x 4¼ in. wide x $3\frac{5}{32}$ in. deep; 5-pole (size 0), same except 4⅝ in. wide; for d-c power coil, add $\frac{7}{16}$-in. to height.

Service: Across-the-line starting with 15-amp (open) ratings as follows; 115 v, single-phase—1 hp; 110 v, 3-phase—1½ hp; 230/440/550 v, single-phase—1½ hp; 220/440/550 v, 3-phase—2 hp; 3 or 5 poles; standard operating coils for above voltages, 25, 50 or 60-cycle; dual-voltage coils for 110/220 or 220/440 v, 60-cycle, or d-c solenoids for 115 or 230 v can be supplied.

Design: Double-break, silver-to-silver contacts; poles can be converted from normally-open to normally-closed by inverting both moving and stationary contacts; laminated-iron magnet frame and plunger; melamine arc hood; any poles may be used as interlock contacts; thermal inverse-time overload relays or mechanical interference type interlocks between adjacent contactors can be added.

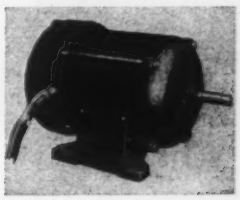
Application: Refrigeration, air-conditioning equipment; machine tools.

For more data circle MD 18, Page 161

SINGLE-PHASE MOTOR 19

. . . flexes horizontally and vertically

General Electric Co., Medium and Small Motor Div., Schenectady 5, N. Y.



To minimize space requirements, starting capacitors of this single-phase, totally enclosed motor are mounted within the frame.

Designation: Tri-Clad KCS.

Size and Service: For service in extreme conditions of dust, grit or moisture; explosion-proof and dust-explosion-proof construction available; 115/230 v, 60-cycle a-c except 5 hp, 230 v only.

Size (hp)	Speed (rpm, sync.)	Frame (NEMA)
1	1800	203
1½	3600	203
	1800	204
2	3600	204
	1800	224
3	3600	224
	1800	225
5	3600	225

Design: Single-phase, capacitor; fan-cooled; aluminum squirrel-cage rotors; ball bearings.

Application: Coal stokers, exaust fans, grain elevator machinery, fuel-pumping machinery.

For more data circle MD 19, Page 161

PRECISION SWITCHES 20

. . . require lower operating force

Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

These single-pole, double-throw switches, requiring a lower operating force than standard type A flexible leaf-actuated switches, are essentially the same in capacity.

Designation: BA-2RV, -2RV2, -2RV22.

Size: BA-2RV, $1\frac{15}{16}$ in. long x $\frac{11}{16}$-in. wide x $1\frac{3}{64}$-in. high with $1\frac{9}{32}$ in. leaf extension; BA-2RV2, same with ⅜-in. min height extension for roller; BA-2RV22, same with $\frac{33}{64}$-in. length, $\frac{23}{64}$-in. height roller-leaf extension.

Service: Listed by UL for 3 hp at 115 v a-c, 1½ hp at 230 v a-c, 20 amp at 125, 250 or 460 v a-c or 10 amp at 125 v a-c on lamp circuits; 0.020 contact-break distance;

Switch	Operating Force (oz, max)	Release Force (oz, min)	Pretravel (in., max)	Overtravel (in., min)
BA-2RV	2½	½	0.625	0.078
BA-2RV2	3½	½	0.468	0.062
BA-2RV22	6	1½	0.250	0.031

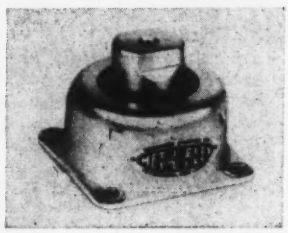
Design: Snap action; single-pole, double-throw; contact separation, 0.020-in.; BA-2RV has straight operating lever, -RV2 has long lever with roller, -RV22 has short lever with roller; solder-lug, integral-screw or side-facing binder-head screw terminals.

For more data circle MD 20, Page 161

VIBRATION MOUNT 21

. . . for small-space requirements

Robinson Aviation Inc., Teterboro Air Terminal, Teterboro, N. J.



This small No. 1 size vibration mount is of all-metal construction and performs in temperature range from −90 to +175 C.

Designation: 7001-H through -M.

Size: No. 1; $1\frac{1}{16}$ in. square, $1\frac{5}{32}$ in. nominal loaded height; weight, 1½ oz.

Service: Model 7001-H, ½ to 1 lb load rating; J, ¾ to 1¾ lb; K, 1½ to 3 lb; L, 2½ to 5½ lb; M, 5 to 10 lb; vertical resonant frequency, 550 cycles per min; axial-lateral stiffness ratio, 4:1; at least 2:1 load range without excessive deflection; gradual snubbing on shock with no solid contact to 15*g*; ultimate strength, 30*g* in accordance with drop-test specified in AN-E-19, minimum 700 lb; ambient temperature, −90 to +175 C; conforms to JAN-C-172A specifications.

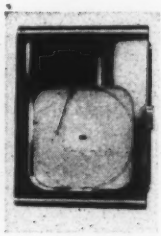
Design: Mounting stud supported by stainless-steel cushion and spring; auxiliary cushion and Monel buffer provide secondary shock protection on excessive positive and negative shock motion, respectively; satin-finish aluminum housing.

For more data circle MD 21, Page 161

RUNNING-TIME RECORDER 22

. . . available in wide ranges

Bristol Co., Waterbury 20, Conn.



Total "on" time in hours, minutes and seconds, can be determined for any time period. Occurrence time and duration of "off" periods is also shown.

Designation: Series 500.

Size: 12-in. chart, 20¾ in. high x 14 in. wide x 5¾ in. deep; 8-in. chart, 14¾ x 10¾ x 5¾.

Service: 115 v, 25 or 60 cycle; 24 v, 60 cycle;

"On" Range (min)	Minimum Graduation (min)	Chart Rotation
	12-in. charts	
0-10	0.2	24 hr
0-60	1	24 hr
0-60	2	24 hr
0-60	2	7 day
	8-in. charts	
0-10	0.2	8 hr
0-10	0.2	24 hr
0-60	2	24 hr
0-60	2	7 day
0-10	0.1	24 hr
0-60	1	24 hr
0-10*	0.1	12 hr
0-10*	0.1	24 hr

* Chart marked in 100 1/10-min intervals

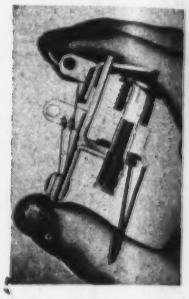
Design: Each travel of pen across chart represents "on" time of duration shown in "on" range above; synchronous motor drives cam when machine is operating, driving pen arm across chart; second motor rotates chart, showing elapsed time on scale concentric with chart center; flush-panel, permanent-mount or portable enclosures; spring chart-drive available.

For more data circle MD 22, Page 161

TIME-DELAY RELAY 23

. . . operates on hydraulic-magnetic principle

Heinemann Electric Co., 309 Plum St., Trenton 2, N. J.



When the coil is energized on this relay, the movable core is drawn into the magnetic field, with rate controlled by a silicone liquid. When the core reaches the top of the coil, increased magnetic flux through the core causes the relay to operate.

Designation: Silic-O-Netic.

Size: 2½ in. high, 1⅝ in. wide, ¾-in. deep.

Service: 10 amp at 120 v a-c or 50 v d-c noninductive; time delay, 5, 15, 30, 45, 60, 90, 120 sec; operating voltage, 6, 12, 24, 48, 120, 220, 250 v; power, 2 w; vibration, 5*g*; recycling time, 0 to 90% operating time, rapid recycling special.

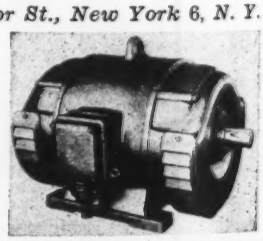
Design: Single-pole single-throw or double-pole, double-throw; sealed tube, containing magnet core and viscosity-stable silicone liquid, extends through and below relay; upward movement of magnet core when coil is energized is controlled by passage of liquid around core, introducing time delay; when core reaches pole-piece, increased magnetic flux causes relay to operate; solder-tab or terminal-screw connections with base plate; dust-protecting, dust and moisture-proof, and tamper-proof housings available.

For more data circle MD 23, Page 161

QUICK-STOP MOTOR 24

. . . with built-in brake

Brown-Boveri Corp., 19 Rector St., New York 6, N. Y.



A built-in brake on this reversible motor operates or releases automatically.

Size and Service: Reversible, 3-phase; releases brake on application of power; stops and brakes with 150% normal torque on power interruption; axial movement of shaft for braking, $\frac{3}{64}$-in.; ratings at 25% load factor, 200 operations per hr as follows:

Synchronous Speed (rpm)	Number of Sizes	Output (hp)	Full-Load Speed (rpm)	Starting Torque (% full load)
		Drip-proof		
1800	5	0.5-8	1600-1715	240-250
1200	5	0.3-5	1100-1140	180-220
900	4	0.45-3.5	810-860	185-150
		Totally-enclosed		
1800	5	0.4-4	1620-1760	230-300
1200	5	0.22-3.5	1090-1030	180-220
900	4	0.33-2.5	820-860	200-165

Design: Conical stator bore and rotor; shaft has $\frac{3}{64}$-in. axial play; brake is mounted on one end of shaft; with power off, spring pressure applies brake and shifts rotor axially out of stator bore; when power is applied rotor is pulled back into stator bore, releasing brake; requires axially elastic coupling, or V or flat-belt drive; drip-proof or totally enclosed construction; horizontal or vertical mounting; base or flange mounts supplied; brake adjustable with locknut.

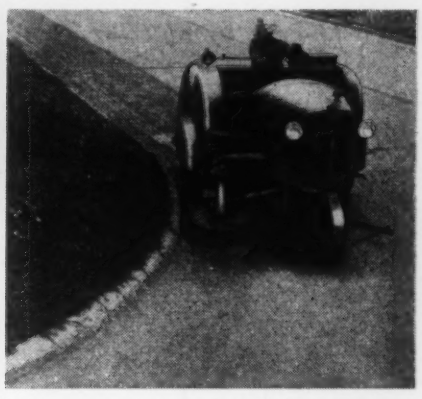
Application: Cranes, winches, hoists, large machine tools.

For more data circle MD 24, Page 161

EXCEPTIONAL PERFORMANCE on mobile equipment

Austin-Western "99-H" Power Grader

Austin-Western Tandem Roller

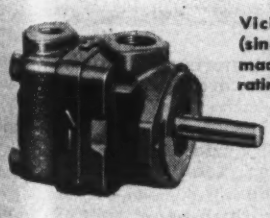


Austin-Western Model "40" Motor Sweeper

...that's why

Austin-Western *uses* VICKERS VANE TYPE PUMPS

Here are some of the reasons for the outstanding performance of the Vickers mobile equipment pump shown below . . . reasons that influenced its selection as the source of hydraulic power for Austin-Western road machinery.



Vickers Balanced Vane Pumps (single) for mobile machinery are made in 10 sizes having delivery ratings from 3.2 to 52 gpm @ 1000 psi and 1800 rpm. Higher pressures and/or speeds also possible. Several mountings and four optional positions of pressure outlet connection. Also available in double pump combinations.

1. Compact, high-efficiency design with many choices of pump size and mounting arrangement SAVES SPACE and also provides INSTALLATION SIMPLICITY.
2. Pump does not load up until engine is up to speed, for EASY COLD WEATHER STARTING.
3. All running clearances automatically maintained as pump wears; PERFORMANCE DOES NOT DROP OFF WITH WEAR.
4. Exclusive hydraulically balanced design neutralizes oil pressure loads on bearings, providing LONG LIFE WITH NO ADJUSTMENTS.
5. Rugged construction makes Vickers mobile equipment pumps TOUGH.

For further information get in touch with the nearest Application Engineering office or write to Detroit for Catalog M-5100.

VICKERS Incorporated *DIVISION OF THE SPERRY CORPORATION*

1430 OAKMAN BLVD. • DETROIT 32, MICH.

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ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

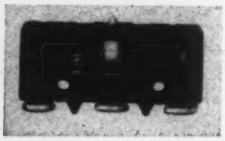
***Ask for* NEW CATALOG M-5100**

4545

LIMIT SWITCH 25

. . . designed for minimum contact bounce

General Control Co., Boston 34, Mass.



Direct action of the leaf spring in this limit switch insures contact at the same fixed point on repeated cycles.

Designation: Du.op.

Size: 1⅛ in. long, 1 in. high, approx. 1 in. wide; No. 8 terminals.

Service: Rating, 20 amp at 125 v a-c, noninductive; low a-c peak temperature rise; limited overtravel.

Design: Single pole, double throw, spring return; plunger actuates direct-action leaf spring; contact blades riveted to terminals; molded phenolic housing; silver contacts.

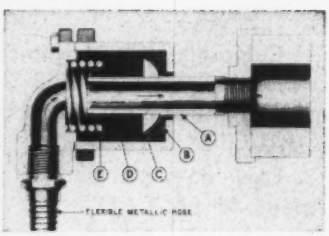
For more data circle MD 25, Page 161

ROTARY JOINT 26

. . . for 250-psi operating pressures

Johnson Corp., Three Rivers, Mich.

Specifically designed for heated rotating rolls, these joints have a carbon-graphite packless seal which supports the joint and automatically adjusts to roll misalignment.



Designation: Type S.

Size: For ¾, 1, 1¼, 1½, or 2-in. pipe in through-flow type, same plus 3-in. for siphon-pipe.

Service: Operating pressure to 250 psi; right or left-hand rotation; self-lubricating; self-adjusting for roll misalignment.

Design: Nipple *A* has hemispherical collar *C* which rotates against carbon-graphite seal ring *B;* carbon-graphite guide *D* maintains pressure against collar; spring *E* supplies initial seating force, with line pressure supplying subsequent seating force; joint supported by seal; cast-iron nipple, head, body; bronze construction, flexible metal hose, mounting flanges available.

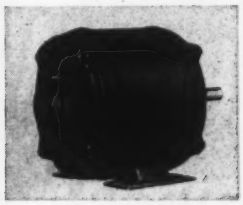
Application: Paper-making, textile, rubber machinery.

For more data circle MD 26, Page 161

FRACTIONAL-HORSEPOWER MOTOR 27

. . . has high starting torque

Century Electric Co., 1806 Pine St., St. Louis 3, Mo.



This split-phase motor having a high starting torque, is for use where high starting current is not objectionable.

Size: ⅓-hp, 10 in. long x 6½ in. wide x 6⅛ in. high; ¼ hp, same except 9½ in. long; NEMA frame C56Z.

Service: Breakdown torque in accordance with NEMA standard; service factor, 1.00.

Design: Cast-iron drip-proof end brackets; welded steel frame; phosphor-bronze sleeve bearings with thrust collar; wool-yarn lubrication; ground steel shaft; high-pressure-cast aluminum rotor, dynamically balanced; plastic insulation; cushion base available.

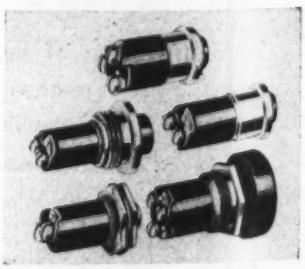
For more data circle MD 27, Page 161

PUSHBUTTONS 28

. . . withstand 10g acceleration

Square D Co., 6060 Rivard St., Detroit 11, Mich.

Recently reinstated in the product line, these aircraft pushbuttons are available in two basic styles.



Designation: Class 9390.

Style: Two-point, 2-terminal, normally-open or closed, single-pole 3-point, single-throw; 3-terminal, normally-open, single-throw.

Service: Rated 15 amp at 30 v d-c to 40,000 ft altitude; resist vibration to 55 cycles per sec, with $\frac{1}{16}$-in. extrusion without arcing; temperatures, −65 to +160 F; acceleration to 10*g*.

Design: All models are for flush-panel mounting and have screw terminals; 2-point models have lock nuts, and steel or bakelite thumb-switch or bakelite mushroom buttons; 3-point models press-fit into mounting hole, have Lucite caps with white disks, plain or printed, black disks with green fluorescent or white letters, or plain fluorescent disks.

Application: Aircraft, tanks, ground communication units.

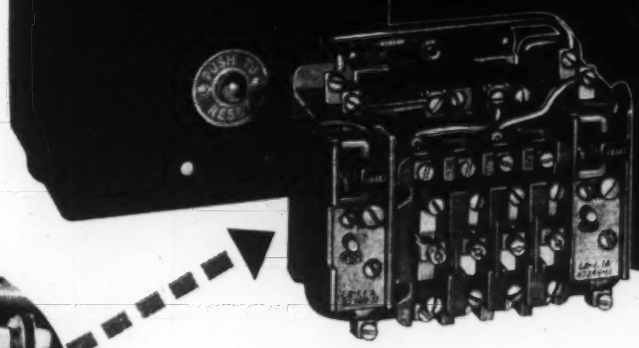
For more data circle MD 28, Page 161

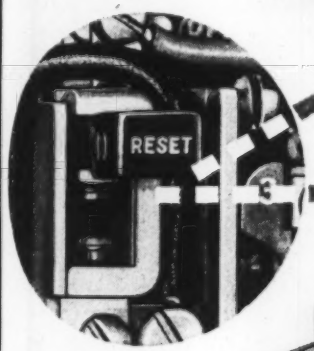
NEW!

R-B-M

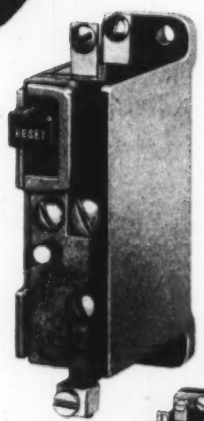
A. C. MAGNETIC STARTERS

Line Voltage Type





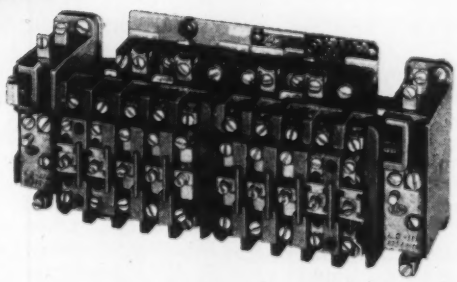
With Visible Contact Overload Relays



- Heater element cannot be assembled to starter incorrectly.
- Bi-metallic thermal overload relay assembly replaceable without removing starter from enclosure. Designed for separate mounting without subpanel assembly.
- TRIP-FREE Manual reset is standard. Manual-Automatic Reset available on special order at no extra cost.

R-B-M Size 0 and 1 A.C. Magnetic Starters have identical overall panel mounting dimensions. All parts, except stationary and movable contact assemblies, are common to both sizes.

Ilsco solderless lugs, suitable for #6 maximum wire size, are standard. Screw terminals are available on special order. Magnet coil can be removed without disassembling starter. Stationary and movable contacts replaceable without disconnecting wiring. Enclosed heater element, expanding U-shaped bi-metal and snap action contact mechanism provide dependable, accurate motor overload protection.



Two 5 pole contactors mechanically interlocked with overload protection on common base. Unwired. Note interchangeability of 25 ampere normally open contacts and 15 ampere convertible N.O. or N.C. interlocks.

Small overall size, plus identical mounting dimensions for 10 and 15 ampere 2 to 5 pole contactors, as well as Size 0 and 1 non-reversing starters, make the R-B-M line extremely flexible for control panel layout.

Address Department B-10

RBM

R-B-M DIVISION ESSEX WIRE CORP.

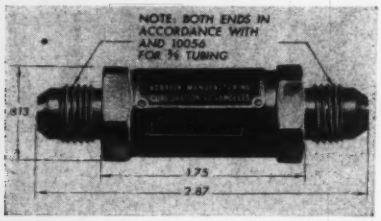
Logansport, Indiana

MANUAL AND MAGNETIC ELECTRIC CONTROLS — FOR AUTOMOTIVE, INDUSTRIAL, COMMUNICATION AND ELECTRONIC USE

PNEUMATIC CHECK VALVE 29

. . . for high-pressure operation

Bobrick Mfg. Corp., 1839 *Blake Ave., Los Angeles* 39, *Calif.*



Size: 0.813-in. diam, 2.87 in. long; weight, 3.4 oz; for ⅜-in. tubing.

Service: Air to 4000 psi, hydraulic to 5000 psi; free flow, 7.0 lb per min, maximum; pressure drop, 150 psi (gage) maximum at 7.0 lb per min with inlet pressure 150 psi (gage, max.); reverse flow, 200 cu in. per min, maximum free-air, at 4000 psi; proof pressure, 9200 psi.

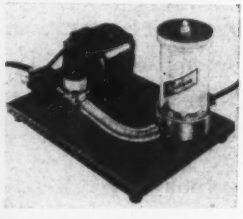
Design: Stainless-steel; outer envelope in accordance with AN 6249-6; both ends in accordance with AND 10056 for ⅜-in. tubing.

For more data circle MD 29, Page 161

FILTER PUMP 30

. . . for small volumes at high pressure

Sethco, 105-07 150*th St., Jamaica* 4, *N. Y.*



Designation: LGI-5.

Size: Base, 12 x 16 in.; height, filter housing, 8½ in.

Service: Filtering light oils, fuel oils, glycerine, glycol, other organic lubricating liquids at 70 gph, 40 psi; motor rating, ⅛-hp, 110 v a-c, 60 cycle, single-phase; pump is self-priming; filter cylinder holds less than 1 pt fluid, all recoverable; filters can be reverse-flush cleaned or cleaned by immersion in acid (for stone filters) or alkali (for carbon).

Design: Spur-gear positive-displacement pump with spring-loaded bypass valve which bypasses liquid back to pump when pressure reaches 40 psi; Lucite cylinder with stainless-steel fittings (steel cylinders available); filter tubes of processed cotton yarn wound around stainless-steel core; porous stone or porous carbon filters available; motor is induction type with ball bearings.

For more data circle MD 30, Page 161

FLEXIBLE TUBING 31

. . . "stays put" without support

Vermont Flexible Tubing Co., Lyndonville, Vt.

Designation: Sealflex.

Size: ID or pipe-thread size by OD, in., ⅛ x 0.350, ¼ x 0.525, ⅜ x 0.600, ½ x 0.840, ¾ x 1.100.

Service: Fluid lines on vibrating or moving parts; seals tighter with increased bending; stays in position without support.

Design: Tension-wound; can be fitted with male or female couplings, nozzles, stopcocks, unions or to specifications.

Application: Machine tools.

For more data circle MD 31, Page 161

MINIATURE MOTOR 32

. . . for 60, 400-cycle or variable frequency

Atlas Aircraft Products Corp., 1 *E. 53rd St., New York* 22, *N. Y.*

Designation: FB-1615.

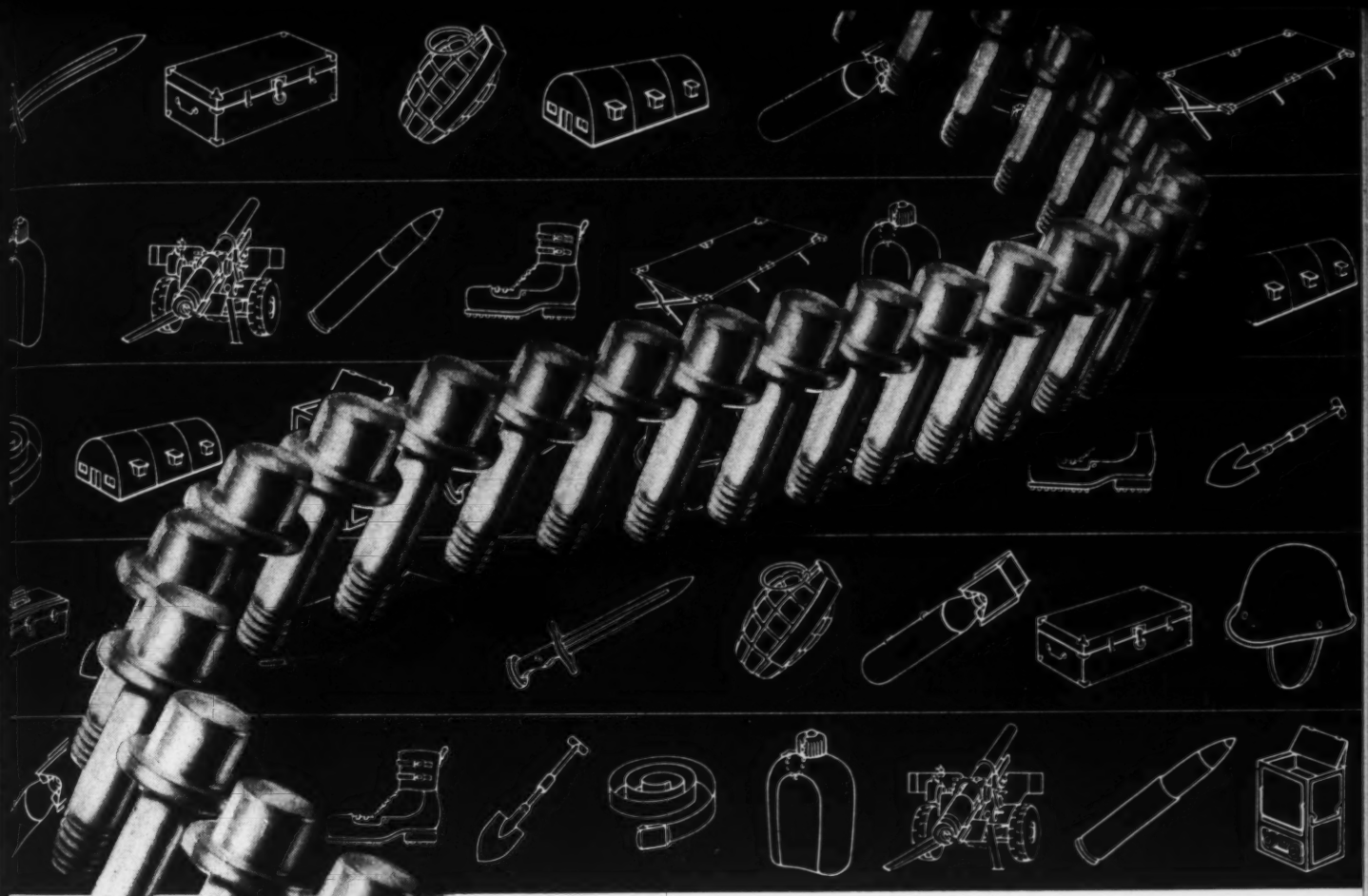
Size: 1¾ in. OD, 2¾ in. long, weight, 16 oz; fan-cooled, 2 in. OD, 3 in. long.

Service: Continuous-duty ratings, 60-cycle, 1/100 hp at 3200 rpm, 1/200 hp at 3600 rpm (synchronous), both single-phase; 400-cycle, single-phase, 1/50 hp at 7200 rpm, 1/35 hp at 10,000 rpm (capacity type), 1/200 hp at 8000 rpm (synchronous); 400-cycle, 3-phase, 1/35 hp at 7200 rpm, 1/25 hp at 10,000 rpm (capacity), 1/100 hp at 8000 rpm (synchronous); 60-cycle, 3-phase available; ambient temperatures to 100 C with type H insulation.

Design: Induction, capacity or synchronous types; totally enclosed, black anodized aluminum housing; type A (continuous-duty) or H (intermittent, silicone) insulation; rotors dynamically balanced; shielded ball bearings.

Application: Aeronautic cameras, fans and blowers for electrical equipment, timing devices, sine-wave alternators.

For more data circle MD 32, Page 161



HERE'S HOW Townsend CUTS STEEL USE AND REDUCES COST ON THIS DEFENSE ITEM

The part shown above for use in a smokeless powder box was originally made from bar stock which wasted hundreds of tons of critical steel. Townsend engineers suggested that by a slight change in design the part could be cold headed from wire thus saving considerable steel and reducing the cost greatly. We are not permitted to reveal the number of parts made, but the aggregate savings both in money and steel was substantial.

This is typical of how Townsend saves time, money and material for customers by drawing upon its long experience in cold-heading to produce quality parts and fasteners with economy. When you work with Townsend in designing and producing military or civilian items you enjoy the benefit of this experience.

Townsend products for defense range from hob nails for field boots to rivets for half tracks — from special nails for gliders to artillery firing pins — even balls for canisters.

To learn more about the savings in time, money and critical materials that are possible when you have Townsend design and produce your small parts and fasteners, write or phone today.

Townsend

COMPANY • ESTABLISHED 1816

Plants—New Brighton, Pa. · Chicago 38, Ill.

Cherry Rivet Company Division, Los Angeles, California

Sales Offices in Principal Cities

For additional information on this new equipment, see Page 161

HAND TACHOMETER 33

. . . reads from 25 to 30,000 rpm

James G. Biddle Co., 1316 *Arch St., Philadelphia* 7, *Pa.*

Not available for the past several years, these German hand tachometers are again being sold and serviced in this country.

Designation: Dr. Horn 480.

Size: Carrying case, 3½ x 2 x 6½ in.; weight, 1¼ lb; weight (tachometer only), ¾ lb.

Service: Six speed ranges, 25-100, 75-300, 250-1000, 750-3000, 2500-10,000, 7500-30,000 rpm with scale divisions, 1, 2, 10, 20, 100, 200 rpm, respectively; protected against overspeeding damage; operates in any position.

Design: Revolving pendulum serves as measuring mechanism; furnished with wheel, extension shaft, rubber and metal points, rubber cone.

For more data circle MD 33, Page 161

PHOTOGRAPHIC PAPER 34

. . . processed in ordinary room light

Eastman Kodak Co., Rochester 4, *N. Y.*

This paper produces black-on-white intermediates for quantity-print production from blueprints and other negative originals.

Designation: Kodagraph Repro-Negative.

Size: Rolls, 8½, 9, 12, 20 in. wide by 60, 100 and 250 ft long, 24, 30, 36, 42 in. wide by 100 and 250 ft long; sheets (in.), 5 x 7, 8 x 10, 8½ x 11, 8½ x 14, 9 x 12, 11 x 14, 11 x 17, 12 x 18, 14 x 17, 17 x 22, 18 x 24, 20 x 24, 24 x 36.

Service: For intermediate black-on-white prints from negative originals; processed with standard photographic chemicals in ordinary room light.

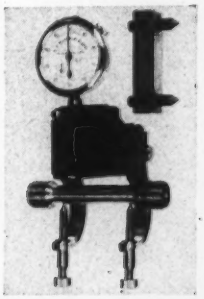
Design: Silver-sensitized, medium-high-contrast emulsion on translucent paper base; Kodagraph yellow or orange sheeting used as filter in front of light source.

For more data circle MD 34, Page 161

MECHANICAL STRAIN GAGES 35

. . . read to 0.0001-inch on dial indicator

F. F. Metzger & Son, 2600 *N. 6th St., Philadelphia* 33, *Pa.*



Size: 2, 4, 6, 8, 10-in. gage lengths; weight, 13 oz.

Service: Measuring axial deformation of metal under test loads; reads to 0.0001-in.; total range, 0.030-in.; accuracy, 0.0002-in.

Design: Hardened tool-steel wearing parts; nickel-plated steel; double multiplying lever with 10:1 ratio magnifies reading; furnished with 2 clamps, punch bar and plush-lined case.

For more data circle MD 35, Page 161

PANEL MATERIAL 36

. . . for mockups and experimental models

Masonite Corp., 111 *W. Washington St., Chicago* 2, *Ill.*

This material is manufactured by a recently-developed process which maintains uniformity of strength, bond strength and modulus of rupture throughout each panel.

Form: Sheet.

Size: 48-in. wide, 36, 72 or 144 in. long; thickness, ¼, ⅜, ½, ⅝, ¾, 1, 1¼, 1½ and 2 in.

Service: Moisture content is constant throughout panel, giving uniformity of strength, bond strength and modulus of rupture.

Properties: Light weight of approx. 0.05 lb per cu in.; less than 3% voids.

Application: Models, mockups.

For more data circle MD 36, Page 161

HELPFUL LITERATURE

FOR DESIGN EXECUTIVES

75. Clips, Clamps & Blocks
Thomas Associates—32-page loose-leaf, plastic bound "Engineering Manual" covers 12,000 types and sizes of bare metal and cushioned electric line support clamps and support blocks for aircraft and industrial use. Prints and specifications cover materials, finishes and sizes in aluminum alloy, steel and stainless, plus related clamps, busbars and shims.

76. Motor Controls
Furnas Electric Co.—4-page bulletin 4401B presents illustrations and descriptive information on line of manual, pedal and automatic electric motor controls. Brief mention is given regarding various handle and lever accessories which are available.

77. Insulated Terminals
Thomas & Betts Co.—Data sheet 24 presents technical information on line of self-insulated Sta-Kon terminals designed for use in cramped quarters to prevent short circuits between adjacent terminals on closely mounted studs. Government specifications and installation methods are included.

78. Cutting & Grinding Facts
Sun Oil Co.—Factual data concerning more than fifty typical metalworking jobs are presented in 80-page illustrated booklet "Cutting & Grinding Facts." Operating data is based upon latest information supplied by leading builders of automatics, grinders, milling machines, lathes and other machine tools. Complete information is given on straight and emulsified cutting oils, together with selection guidance.

79. Worm Gear Speed Reducers
Eberhardt-Denver Co. — 6-page illustrated folder No. 1000 lists dimensions and specifications of stock single and double reduction and heavy duty worm gear speed reducers. Shaft arrangements to meet practically any need can be provided.

80. Reproduction Process
Haloid Co.—4-page illustrated bulletin X-1 cites case history of use of Xerography equipment and process for making paper masters of price lists, bulletins and technical articles for reproduction on Multilith Duplicators.

81. Vibration Mounts
American Felt Co.—20-page illustrated booklet "How to Reduce Vibration" is guide to selection and application of proper grade and weight of vibration mounting felt for various types and sizes of machines and equipment. Transmitted vibration from machine to floor can be reduced up to 85 per cent by using correctly installed Vibra-Mount felt.

82. Investment Castings
Jelrus Co.—Applications and advantages of Jelrus precision investment casting of small close-tolerance parts of any castable alloy are explained in 4-page illustrated bulletin. Producible with intricate contours, investment castings are made to any design requirement.

83. Blowers & Exhausters
Lamson Corp., Allen Billmyre Div.—20-page illustrated bulletin B-5 describes complete line of centrifugal type blowers and exhausters. Machines range from small fractional-horsepower unit to 250-hp models. Ordering and technical data presented includes pressure conversion units, suggested applications and other information.

84. Pyrometers & Controls
Assembly Products, Inc.—Listings of sizes, ranges and prices plus technical information on Simplytrol contact meter-relays, controls, pyrometers and panel meters and relays is presented in 35-page catalog No. 1-A. Circuit diagrams and installation and operating instructions are included.

85. Vibrating Screens
Link-Belt Co.—Model UP vibrating screens for accurate dry-screening of light and fine materials and model NRM liquid vibrating screens for high speed separation of solids from liquids are described and their specifications listed in 20-page catalog No. 2377.

86. Meehanite Case Histories
Meehanite Metal Corp. — Twelve case histories of unusual applications of Meehanite castings in various industries are included in 8-page illustrated folder "25 Years of Proof in Service."

87. Industrial Cork Products
Dodge Cork Co.—Characteristics and uses for cork compositions and natural cork is subject of 4-page illustrated bulletin 1h-D. Included are tables giving physical properties, sheet sizes and equivalents of Government specifications.

88. Speed Control & Drive
Electric Machinery Mfg. Co.—Technical in scope, 32-page illustrated publication 1107 contains information on precision speed control with adjustable speed magnetic drive. Industrial applications, plus many charts and diagrams are included.

89. Socket Screw Products
Holo-Krome Screw Corp.—Design and engineering information on line of cold forged socket screws and special products is featured in revised catalog No. 51. Items covered include socket set, socket head cap and flat head socket cap screws; socket head stripper bolts; socket pipe plugs and button head socket cap screws.

90. Stainless Corrosion Data
Carpenter Steel Co., Alloy Tube Div.—Corrosion resistance information for several analyses of stainless steel tubing and pipe are listed on 12 x 9-in. wall chart. Reverse side contains size, dimensions, pressures and tolerances for stainless pipe in schedules 5, 10 and 40.

91. Threaded Bars
Joseph T. Ryerson & Son, Inc.—Single data sheet "Ryerson Threaded Bar Service" contains data on size range, lengths, kind of threads, bending, types and finishes of threaded steel bars. Accessories including turnbuckles, nuts, washers and tank lugs are also shown.

92. Threads, Plugs & Rings
Republic Gage Co.—A possible aid to designers of parts for production is this Standard Gage thread, plug and ring catalog which is all-inclusive and accurate. Illustrations and drawings are included whenever they can contribute to easier interpretation of data.

93. Diamond Abrasive
Elgin National Watch Co., Abrasive Div.—4-page folder No. 5000851 introduces Dymo-C, a diamond abrasive prepared especially for lapping and polishing carbide drawing and heading dies. It details specific performance and application advantages. Catalog and price data are included.

94. Rubber Parts & Equipment
Automotive Rubber Co.—Company has prepared 12-page illustrated catalog describing its plant facilities for producing sheet rubber-lined tanks and form-dipped rubber parts. Their new rubber compounding mill and various products and services are covered.

FOR MORE INFORMATION

on developments in "New Parts" and "Engineering Department" sections—or if "Helpful Literature" is desired—circle corresponding numbers on either card below

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95. Electrical Fittings

Buchanan Electrical Products Corp.—12-page illustrated catalog 1050 describes line of solderless wire connectors, cable and conduit fittings, and wiring devices. Special attention is given to pres-SURE-connectors for solderless wire splicing and terminating, plain and insulated conduit bushings, box connectors for metallic and nonmetallic sheathed cables, knockout plugs and molded terminal blocks.

96. Fiber Products

Spaulding Fibre Co.—Applications of various types of fiber materials and fabricated parts are tabulated by industries in 8-page illustrated bulletin "Spaulding Products for All Industries." In addition, actual samples of typical fiber parts are included in separate glassine envelope.

97. Material Surface Inspection

Brush Development Co., Instrument Div.—"Surface Evaluation by Faxfilm" is title of 8-page folder describing applications of Faxfilm for inspection, test and process engineering, as well as equipment used. This process employs plastic replica to show wear, grain and other surface conditions of various materials.

98. Air Cylinders

Rivett Lathe & Grinder, Inc.—Illustrated and described in catalog No. 55 are 28 different air cylinder models, each in nine bore diameters. Working drawings and specifications are furnished for each model and size. Cylinders are for air pressures of 150 psi and oil pressure of 300 psi maximum.

99. Nickel Pipe & Tubing Design

International Nickel Co.—28-page technical bulletin T-17 on fabrication and design of nickel and high nickel alloy pipe and tubing contains drawings, photographs, tables of mechanical and physical properties, ASME code requirements, recommended welding procedures and other data.

100. Precision Nylon Balls

Ace Plastic Co., Industrial Div.—2-page bulletin No. NP-101 provides information on nylon balls for valves and components, specialized antifriction bearings, detents and mechanical checks. They are made to plus-minus tolerances of 0.001-in. on diameter and sphericity.

101. Corrosion Resistance of Copper

American Brass Co.—Chemical and physical nature of corrosive attack in its various forms on copper and copper alloys is explained in this 24-page illustrated booklet B-36. Included is tabulation indicating relative corrosion resistance of principal types of alloys in contact with 183 corroding agents.

102. Electric Brakes & Clutches

Warner Electric Brake & Clutch Co.—General data on design and application of industrial electric brakes and clutches is found in handbook No. 701-A. It also presents unit sizes, mounting dimensions and engineering performance specifications.

103. Speed Reducers

Abart Gear & Machine Co.—Designers and draftsmen interested in speed reduction will find valuable aid in this 96-page pocket-size edition of the "Speed Reducers and Gearmotors" catalog. It offers engineering data on how to select proper reducer to fit requirements, including horsepower ratings, ratios and installation graphs.

104. Iron & Alloy Castings

Hamilton Foundry & Machine Co.—In addition to presenting technical data and typical examples of light and medium gray iron, alloyed iron, Meehanite and Ni-Resist castings, 48-page illustrated "Hamilton Quality Castings" booklet describes facilities of company to produce castings to user's specifications.

105. Air & Hydraulic Devices

Logansport Machine Co.—"The Facts of Life on Air and Hydraulic Devices" is reprint of 1949 pocket-size booklet which presents concise data on "do's", "don'ts" and "what to look for" phases of selection, application and operation of this equipment. Material is offered as service to tool engineers and designers.

106. Mercury Switches

Minneapolis-Honeywell Regulator Co.—4-page illustrated catalog No. Hg-1 covers five most popular designs of mercury switches with selection and application aids and complete electrical ratings and data for use of switches in alternating and direct current applications. Price and discount list D-59 is supplemented.

107. Thin Electrical Steels

Armco Steel Corp.—32-page illustrated booklet "Armco Thin Electrical Steels" presents 21 pages of charted curves giving magnetic properties of three iron-silicon alloys—Tran-Cor T, a non-oriented grade; Tran-Cor T-O-S, an oriented alloy; and Tran-Cor T-O-S, a super oriented grade. Curves show core loss, exciting rms volt-amperes per pound, alternating current permeability, induction versus frequency, figure of merit and lamination factor.

108. Duck & Rubber Packings

Raybestos-Manhattan, Inc., Packing Div.—Low pressure, cross expansion, hydraulic, hollow core, round rubber core and diagonal expansion types of duck and rubber packings are detailed in 8-page illustrated bulletin which also gives application and design recommendations.

109. Surface Hardening Compound

Eutectic Welding Alloys Corp.—Eutectic Instant Hardener for emergency surface hardening using ordinary welding torch is discussed in 6-page illustrated folder 512. Product will harden steel tools, parts, edges, threads, files and drills.

110. Feeders & Conveyors

Jeffrey Mfg. Co.—Wide variety of materials can be handled by Jeffrey-Traylor electric vibrating feeders and conveyors, described in detail and illustrated in 84-page catalog 830. Features of design and application information are included, along with control data.

111. Miniature Variable Speed Drive

Metron Instrument Co. — Illustrated data sheet 4C page 1 contains general information on type 4C miniature variable ratio speed changer with push rod adjustment. Application information and dimensional drawings are included.

112. Locking Fasteners

Lion Fastener, Inc.—12-page catalog presents specifications of Lion one-piece fasteners which are locked and unlocked by a quarter turn. Fastener fits into full floating cantilever spring assembly. Installation instructions, tools required, strength characteristics and general information are found in illustrated catalog.

113. Tubing & Pipe Stock List

Babcock & Wilcox Tube Co.—Range of sizes and analyses of alloy and stainless steel tubing and pipe available for immediate shipment are listed in No. 103 stock list. Quantity, OD and wall thickness and length information is given for each analysis.

114. Squirrel-Cage Induction Motors

Allis-Chalmers Mfg. Co.—Construction features and specifications of squirrel-cage induction motors of end shield type are covered in 6-page folder 05B7542A. Motors are offered from 60 to 2000 hp and up to 1800 rpm.

115. Battery Charger

Electric Products Co.—Illustrated bulletin 11-220 outlines design features of four-circuit motor generator battery charger which any truck driver can operate. Unit is self-contained, fully automatic and compact.

116. Aluminum Castings

Aluminum Industries, Inc.—Company's facilities for producing various size aluminum castings ranging in weight from 1 oz to 1000 lb are described and pictured in 4-page bulletin No. 20 A. X-ray and other flaw detection equipment are shown as well as various plant departments.

117. Miscellaneous Taps

DoALL Co.—Illustrations and specifications on hand, machine screw, nut, pulley, pipe, tapper, hook and special taps are included in 16-page catalog No. 51-813. Nine pages of technical data and ordering suggestions completes the catalog.

118. Large Induction Motors

Ideal Electric & Mfg. Co.—4-page illustrated bulletin No. 501 outlines types of large high speed induction motors. Application data and construction features of polyphase squirrel-cage and polyphase slip ring induction motors are included.

119. Vest Pocket Welding Guide

Hobart Brothers Co.—Information on metals and electrodes, four essentials of proper welding procedures, color marking for electrode identification, types of joints, typical positions, causes of welding troubles and other handy references are contained in 40-page booklet "Hobart Welding Electrodes and Welders' Vest Pocket Guide."

120. Welded Tubing

Nikoh Tube Co.—Company organization, production facilities, quality control and application information are subjects detailed in 32-page illustrated catalog. Tubing reference tables complete the issue.

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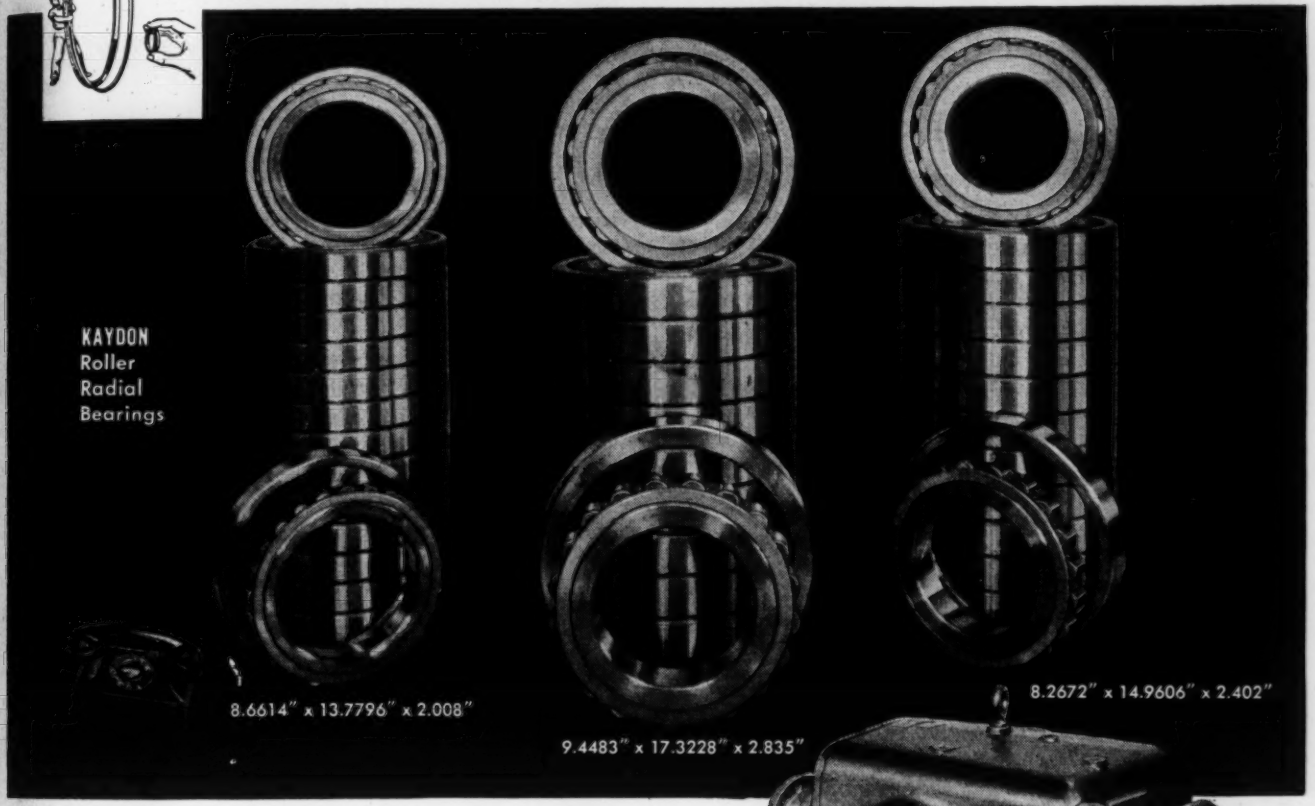
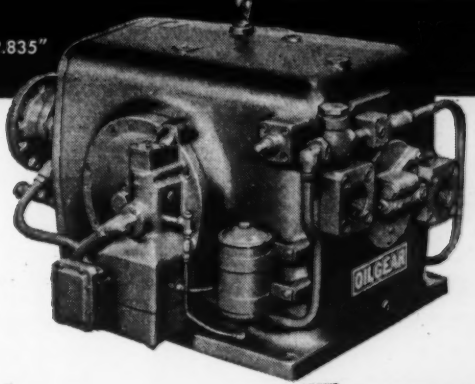
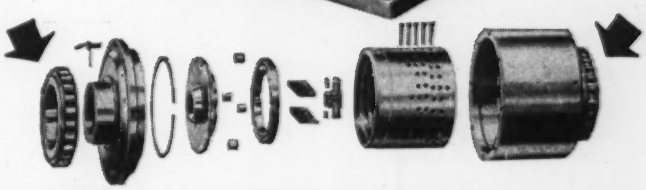


KAYDON and OILGEAR
cooperate for compact design



OILGEAR engineers, pioneering Fluid Power Pumps and Motors, achieved greater compactness and efficiency than ever before considered possible. KAYDON Engineers, pioneers in Thin-Section Precision Bearings, created bearings that were "right at home" at the high level of OILGEAR advanced design.

KAYDON Precision Bearings and Needle Rollers have helped many machinery builders achieve modern design with fewer parts, greater compactness, reduced weight, precision smoothness in operation . . . advantages that improve production, cut costs, and carry impressive sales appeal.



OILGEAR This exploded view shows KAYDON Front and Rear Roller Rotor Bearings with relation to other parts of the 150 hp OILGEAR Fluid Power Variable Delivery Pump (above) for machinery with operating-pressures up to 3000 pounds per square inch . . . with smooth, quiet, startlingly new fluid power performance characteristics. KAYDON Bearings are used also on 60 hp and 100 hp OILGEAR Fluid Power pumps.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

MEN OF MACHINES

Fred Bohle has been appointed manager of the recently organized machine tool development department of Illinois Tool Works, Chicago. He will have authority over all phases of development, design, production and sales of the company's machines. These include special gear and cutting tool inspection equipment, die filing machines, power screw drivers and special machinery developed by the company for its own manufacture in its Shakeproof and Tool Divisions. Formerly chief engineer of the Tool Division, Mr. Bohle has been associated with Illinois Tool Works since 1935.

♦

Appointment of **C. R. Irvine** as assistant division manager and chief engineer of the Convair guided missile division has been announced by Consolidated Vultee Aircraft Corp. Mr. Irvine is an aeronautical engineering graduate of the University of Michigan. He was a consulting engineer in Ann Arbor, Mich., during 1929 and, after serving as chief engineer of the Whittelsy Manufacturing Co., Bridgeport, Conn., joined Stinson Aircraft Co. as a project engineer. In 1931 Mr. Irvine joined the engineering staff of Vultee Aircraft Co., Downey, Calif. These latter two companies later were merged with Consolidated Aircraft Corp., forming the present Consolidated Vultee Aircraft Corp. At Vultee, from 1942 until he was transferred to the Consolidated San Diego Division in 1947, he served as chief development engineer. In San Diego he was chief engineer for missiles and fighter aircraft until appointment as assistant chief division engineer in 1948.

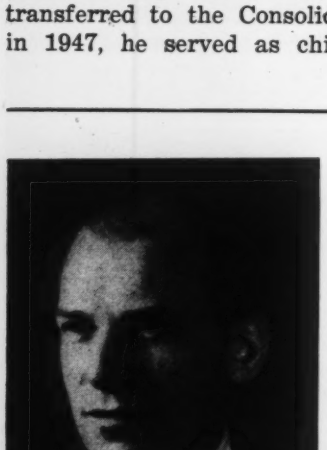
Announced concurrently was the appointment of **Harold W. Pope,** formerly a San Diego Division missile project engineer, as assistant chief engineer of the guided missile division. Mr. Pope holds an aeronautical engineering degree from Massachusetts Institute of Technology. Prior to joining Consolidated in 1940 he served as an Army Air Corps engineer at Dayton, O. He was transferred from the Vultee division to San Diego in 1947.

♦

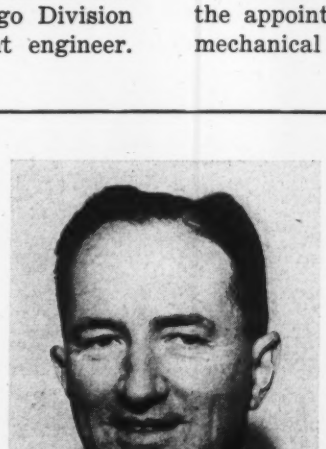
At the July meeting of the board of directors of Micromatic Hone Corp., Detroit, **William H. Harris Jr.** was elected vice president in charge of engineering. Mr. Harris has been associated with the company for 16 years, and before his new appointment served as chief engineer. He holds several honing patents and has contributed articles to various technical publications. Mr. Harris is a graduate of Michigan College of Mining and Technology and is a member of the Society of Automotive Engineers and the Engineering Society of Detroit.

♦

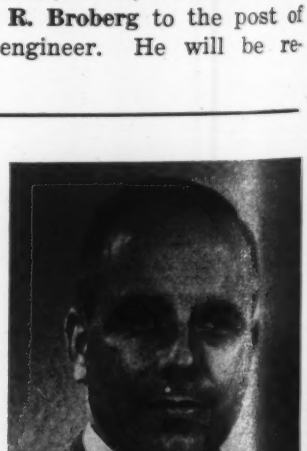
The Lamson Corp., Syracuse, N. Y., has announced the appointment of **Orrin R. Broberg** to the post of mechanical development engineer. He will be re-



Fred Bohle



C. R. Irvine



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sponsible for the design of all new Lamson products and will also formulate plans, policies and procedures for carrying out the mechanical development program. Mr. Broberg was transferred from the company's operations in California to his present position in Syracuse.

♦

H. Stanley Bimpson has been named to the office of the director of engineering of Allis-Chalmers general machinery division as consulting engineer. Mr. Bimpson has been with the company since 1920 and during this time has served in various capacities in the engine and condenser and blower and condenser departments. Since 1947 he has been chief engineer of the blower and condenser department.

♦

Bowser Technical Refrigeration division, Bowser Inc., Terryville, Conn., has appointed **Norman R. Miller** and **Littleton Strong** to the positions of project engineer and research engineer, respectively.

♦

The appointment of **Donald Goodwill** to the position of chief engineer has been announced by The Lees-Bradner Co., Cleveland, manufacturer of gear hobbing and threading machines. Mr. Goodwill joined the company in 1934 and has served as assistant chief engineer since 1940.

♦

Associated with aircraft engine development work for 29 years, **Ralph N. DuBois** has been appointed chief product engineer of the Ford Motor Co. aircraft engine division, Chicago.

♦

All engineering functions of Automatic Transportation Co., division of Yale & Towne Mfg. Co., have been integrated under a single direction. **B. I. Ulinski,** director of engineering, is responsible for management of all engineering functions including research, product design, test engineering and special engineering services. He is succeeded as chief engineer of rider-type industrial trucks by **Ressler A. Dusseau,** formerly his assistant and also manager of engineering cost control.

♦

To specialize in electronics development, **Charles E. Peach** has been appointed chief radar engineer on design and analysis by Zenith Plastics Co., Gardena, Calif.

♦

A number of new appointments were announced recently by General Electric Co. In the Fractional Horsepower Motor Engineering divisions at Fort Wayne, Ind., **J. Herbert Behm** has been named assistant to the manager of engineering on special assignments; **Lee R. Beard,** as division engineer of the A-C Motor Engineering division; **Ray D. Jones,** as division engineer of the Development Engineering division; and **I. E. Ross,** as division engineer of the D-C and Specialty Motor Engineering division. Formerly manager of engineering of the company's Control divisions at Schenectady, N. Y., **James H. Goss** has been appointed staff assistant to **Nicholas M. DuChemin,** general manager of the Small Apparatus divisions. Succeeding Mr. Goss is **Dr. Louis T. Rader,** who has announced the appointments of **Harry L. Palmer** as assistant to the manager of engineering of the Control divisions and **Benjamin Cooper** as division engineer of the Electronics and Regulator Engineering division. Also, **David C. Prince,** a vice president of the company on the president's staff and formerly head of the General Engineering and Consulting Laboratory, has retired after 32 years of service. He plans to enter the consulting engineering field with headquarters in Schenectady.

♦

Linear Inc., Philadelphia, has announced the promotion of **John H. Swartz** to the position of chief engineer. He will direct all engineering activities for both the industrial and aviation fields.

♦

Dr. Donald H. Loughridge, formerly scientific adviser to the Secretary of Army, has been appointed assistant director of the Atomic Energy Commission Division of Reactor Development.

♦

Announcement has been made of the appointment of **Dr. Edward U. Condon** as director of research and development of Corning Glass Works, Corning, N. Y. Dr. Condon formerly served as director of the National Bureau of Standards. He replaces **Dr. Jesse T. Littleton,** who becomes general technical adviser.

♦

As part of a program to increase the scope of its engineering and production facilities, Flexible Tubing Corp. has appointed **Leo Martin** as machine design engineer in charge of the machine development and design laboratory. Manufacturing activities are now located in a new, enlarged plant at Guilford, Conn.

♦

Walter L. Luli was named chief engineer of the coach division of White Motor Co., with headquarters at the coach plant, Cleveland.

♦

The Wel-Met Co., Kent, O., has announced the appointment of **Don S. Urquhart** as product engineer. For the past 16 years Mr. Urquhart served in a similar capacity for the U. S. Graphite Co.

♦

Duncan B. Gardiner has been appointed assistant chief engineer of Vickers Inc., division of the Sperry Corp., Detroit. Since 1944 Mr. Gardiner has been chief product development engineer, after serving a total of 16 years as a product engineer in the company's Navy, industrial and aircraft divisions.

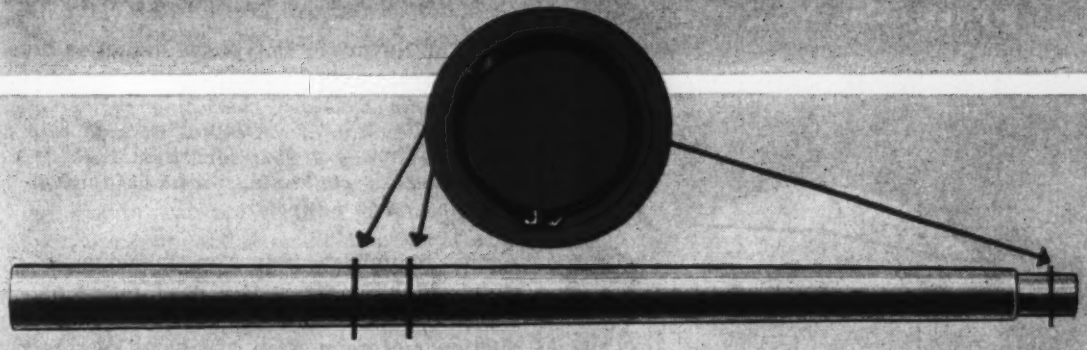
♦

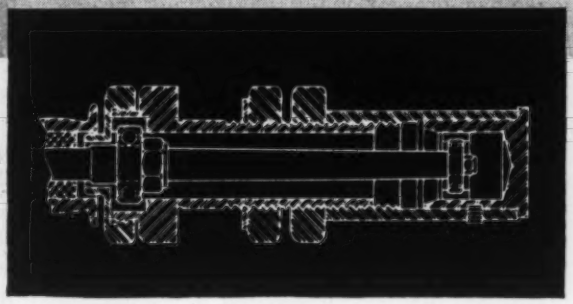
Robert N. Merk was recently appointed chief engineer of Sharon Steel Corp., Sharon, Pa.

♦

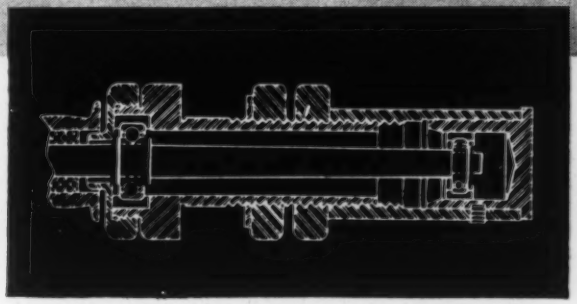
Appointment of **Dr. Raymond C. Machler** as director of research and a member of the executive committee of Leeds & Northrup Co., Philadelphia, has been announced. Associate director of research since 1948, Dr. Machler joined the company in 1929 as a research engineer.

3 TRUARC RETAINING RINGS LOWER COST... IMPROVE PERFORMANCE OF REVOLUTIONARY NEW TEXTILE SPINDLE!





OLD CONSTRUCTION. To position 2 ball bearings, an oversize diameter rod had to be turned on a lathe to provide 3 shoulders. In addition, blade required 2 threading operations . . . 2 lock nuts . . . separate tapering operation. Proper pressure of nuts against ball bearings required skilled labor adjustment.



NEW CONSTRUCTION. Standard rod, equal in diameter to finished blade is used. Three grooves for Truarc Rings and shoulder are made quickly and easily on screw machine. Blade is economically tapered by centerless grinding. Truarc Rings maintain correct pressure on ball bearings for life of unit!

The H & B American Machine Company's new anti-friction CENTURY spindle is probably the most mechanically advanced spindle on the market today. Waldes Truarc Retaining Rings have eliminated many of the material, tooling and assembly costs...have kept its price competitive. Truarc Rings not only simplify spindle assembly, they position ball bearings accurately...simplify maintenance...eliminate skilled labor...improve performance! And there are Truarc Rings to solve any design or re-design problem!

Redesign with Truarc Rings and you too will cut costs.

Wherever you use machined shoulders, bolts, snap rings, cotter pins, there's a Waldes Truarc Retaining Ring designed to do a better job of holding parts together.

Truarc Rings are precision-engineered...quick and easy to assemble and disassemble. Always circular to give a never-failing grip. They can be used over and over again.

Find out what Truarc Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

Waldes Truarc Retaining Rings are available for immediate delivery from stock, from leading ball bearing distributors throughout the country.

SEND FOR NEW BULLETINS ➡

WALDES

TRUARC

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RETAINING RINGS

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS: 2,382,947; 2,382,948; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,081 AND OTHER PATENTS PENDING.

Waldes Kohinoor, Inc., 47-16 Austel Place, L. I. C. 1, N. Y.

Please send engineering specifications and data on Waldes Truarc Retaining Ring types checked below.

- ☐ Bulletin #5 Self-locking ring types
- ☐ Bulletin #6 Ring types for taking up end-play
- ☐ Bulletin #7 Ring types for radial assembly
- ☐ Bulletin #8 Basic type rings

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This new Ward Leonard handbook illuminates a hitherto neglected subject

Somehow—resistors, particularly power resistors, have never been given adequate attention in electrical industry literature.

Now Ward Leonard engineers have filled in the gap with the new *Handbook of Power Resistors*—nearly 200 pages packed with everyday, useful information on resistor types, characteristics, criteria for selection, other helpful data.

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This handbook is modestly priced at $3.00. Order from WARD LEONARD ELECTRIC CO., 58 South Street, Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

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Result-Engineered Controls Since 1892

RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

THE ENGINEER'S Library

The Nature of Polyphase Induction Machines

By Philip L. Alger, consulting engineer, small and medium motor div., General Electric Co.; published by John Wiley & Sons Inc., New York; 393 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$7.50 postpaid.*

The polyphase induction machine is one of the simplest and most widely used forms of electric machine in use today, and the two hundred million induction motors now in use have long been taken for granted by industry and the engineer. Yet these basic machines present many challenging problems to the motor designer and user. This book attempts to give an understanding and visual perception of polyphase induction machines, plus some familiarity with the numerical prediction of their behavior.

Discussed in the first three chapters are basic principles of analysis, circuit analysis and the revolving magnetic field. The second three chapters, on the polyphase induction motor, performance calculations for this type of motor, and the design of induction machines, are drawn for the most part from previously published material. New information on reactance calculation, locking and crawling torques, and magnetic noise is included in the next four-chapter section. The following chapter, on ratings and applications of polyphase motors, represents the author's philosophy on ratings, based on his thirty years of experience in the field. The final chapter explains Gabriel Kron's generalized method of analysis and applies this advanced method to several induction machine problems.

□ □ □

An Introduction to the Theory of Control in Mechanical Engineering

By R. H. Macmillan, demonstrator, University of Cambridge; published by Cambridge University Press, London and New York; 195 pages, 7 by 10½ inches, clothbound; available through MACHINE DESIGN, *$6.00 postpaid.*

For an intelligent appreciation of the value and use of automatic controls, servomechanisms and regulators, an engineer must have a knowledge of three factors. First is a clear understanding of the method of operation of controls; second, an ability to estimate the performance needed in a proposed control system; third, the insight to design a control which will perform as specified while maintaining an acceptable standard of stability. This first British book on the subject keeps the above aims in view while

explaining the fundamental theory of control and control mechanisms.

The first chapter introduces the basic concepts of control and explains the various systems of classification. A consideration of essential control-system components and the transfer function follows. From these fundamental concepts, generalized equations of motion for typical control systems are developed in the third chapter, and in the fourth, methods for analyzing the quantitative performance of these systems are given. More complex servo systems are then treated, with the next two chapters devoted to analytical and graphical methods of determining solutions of the generalized equations, and of determining criteria of stability for complex controls. Since the last three chapters require an understanding of complex numbers and the Laplace transformation, an appendix covering these methods is included.

□ □ □

Design of Machine Members

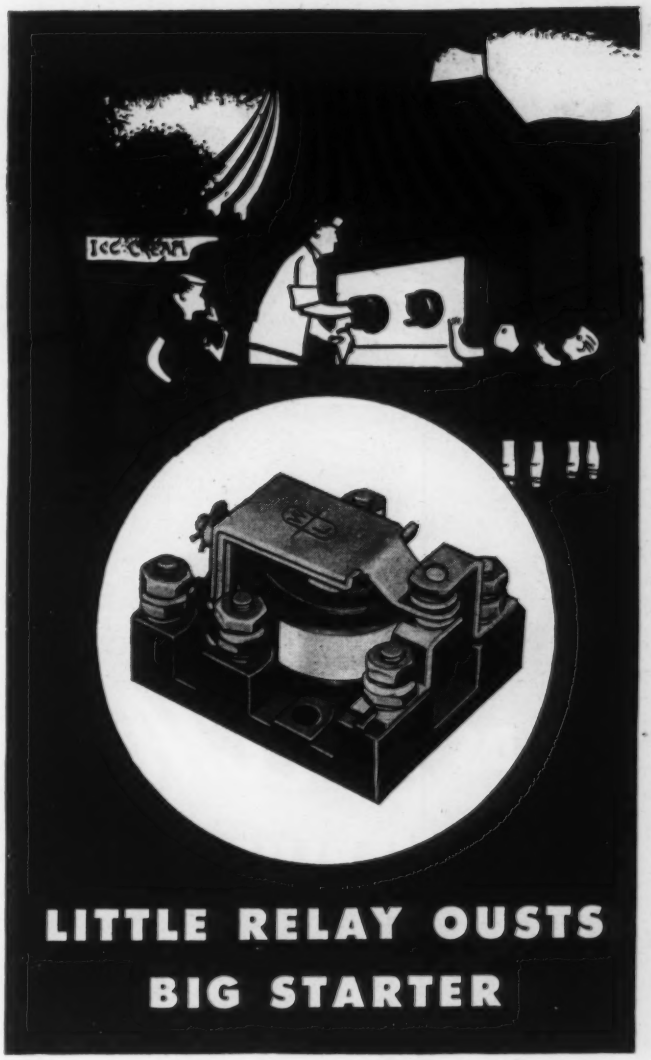
By Alex. Vallance, late chief designer, Reed Roller Bit Co. and Venton Levy Doughtie, professor of mechanical engineering, University of Texas; published by the McGraw-Hill Book Co., New York; 500 pages, 6 by 9 inches, clothbound; available through MACHINE DESIGN, *$6.00 postpaid.*

This third edition has been expanded and revised to include new material on stresses, joints, fasteners, power screws and chains. Notations have been made consistent and standard, and new illustrations and problems have been added.

Materials and stresses are covered first in three chapters, followed by a discussion of cylinders and pipe, metal fits and tolerances, and the use of flat plates and cylinder heads. Various fastening methods and joints occupy four chapters, after which shafting, power transmission and bearings are treated. Three chapters discuss springs and gears. The last sections of the book cover conveyors, belts, and rope and chain drives, with a final chapter on miscellaneous machine members.

New Standards

Tolerances for Ball and Roller Bearings, ASA B3.5-1951: This standard establishes tolerances and limits of size governing dimensional interchangeability of various types of bearings. The standard contains fifteen tables specifying tolerances on the bore, outside diameter, width and other characteristics in different grades of accuracy required for various bearing applications. Types of bearings covered are: annular ball; cylindrical roller (including journal); magneto; airframe; thrust ball; industrial and airframe needle; and tapered roller bearings. Specifications are also given for the maximum permissible variation in diameter between the largest and smallest ball or roller in any assembled bearing; for the hardness of balls,



LITTLE RELAY OUSTS BIG STARTER

and saves customer both space and money

An ice cream freezer manufacturer* was perfectly content with the across-the-line starters used in his equipment.

But we got the idea of saving him some room and dollars by substituting Ward Leonard heavy-duty midget *relays.*

It's a really rugged relay, and certain types are Underwriters' listed as motor controllers. Months of testing proved that a standard Ward Leonard relay with just slight changes would do the job of the heavier starter.

It's another case of Ward Leonard "Result-Engineering" Write us for Bulletin 105 on the heavy-duty midget relay, or for *any* control problem, write WARD LEONARD ELECTRIC CO. 58 South Street, Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

*Sweden Freezer Manufacturing Company, Seattle, Washington.

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Result-Engineered Controls Since 1892

RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

rings and rollers; and for snap ring and groove dimensions.

Copies of this 20-page standard may be obtained from the American Standards Association, 70 East 45th St., New York 17, N. Y., at $0.75 per copy.

Revised ASTM Standards: The American Society for Testing Materials announces the publication of the 1950 Supplements to the Book of ASTM Standards, last published in 1949. The specifications, tests and definitions included are those newly issued in 1950 or revised since their appearance in the 1949 book. The six parts comprising the complete set of supplements are:

Part 1—Ferrous Metals; 66 standards, 328 pages.

Part 2—Non-Ferrous Metals; 42 standards, 232 pages.

Part 3—Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Waterproofing Soils; 68 standards, 364 pages.

Part 4—Paint, Naval Stores, Wood, Adhesives, Paper, Shipping Containers; 54 standards, 352 pages.

Part 5—Textiles, Soaps, Fuels, Petroleum, Aromatic Hydrocarbons, Antifreezes, Water; 93 standards, 596 pages.

Part 6—Electrical Insulation, Plastics, Rubber; 30 standards, 296 pages.

Copies are available at $3.50 per part or $21.00 for the complete set from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Drill Drivers (Split-Sleeve, Collet-Type) ASA B5.27-1951: Complete specifications for split-sleeve collet drivers for straight-shank drills up to 11/16-inch are shown. This range covers practically the entire range of split-sleeve collets produced in quantity, with the exception of limited-use large sizes. It is pointed out that issuance of the standard is not a recommendation of the style of collet, since other types of collets do not require close-tolerance assembly of drill to driver. Copies of this 7-page standard are available from the American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., at $0.45 per copy.

Manufacturer Publication

Solder, Its Nature, Properties and Uses: Although published by a commercial metals firm, this 36-page booklet is basically an editorial treatise. Separate sections are devoted to thermal effects, mechanical properties, principles of soldering, and fluxes. Next the selection of the proper solder for a job is explained. Fusible alloys—those with low melting points—are described. Following a list of practical applications and a description of Federated solders is a summary of specifications and technical data. This section includes the melting range of tin-lead solders; ASTM, SAE, federal and military specifications; and wire tables. Copies are available at no charge from Federated Metals Div., American Smelting and Refining Co., 120 Broadway, New York, N. Y.

"Gravy ON YOUR HAIR?"

Just because gravy goes swell over noodles, he shouldn't assume it's good on hair, too!

And just because one bearing is best lubricated by one particular grade of oil, you shouldn't assume that the same oil is best for *all* bearings on that machine. In many cases it isn't.

OIL CUPS permit you to lubricate each bearing with the oil best suited to that bearing—thus prolonging bearing life, reducing maintenance costs, cutting down-time, boosting production. And oil cups fortunately *cost very little.*

Gits oil cups have been the standard for industry for more than 40 years. Gits Bros. has the largest selection of oil cups available anywhere. Call on Gits Bros. for a prompt, efficient solution to your lubrication problems.

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Through the years, Lovejoy Flexible Couplings have been giving outstanding performances. They feature free-floating load cushions which are suspended between heavy metal jaws. There is no metal-to-metal power transmission and less wear on bearings and shafts. They instantly, permanently correct for angular, parallel or combination angular parallel misalignment. They also absorb vibration, shock, backlash and surge. Cushions are available for every duty . . . 1/6 to 2500 h.p. and last two to five years before changing. For the best in coupling performance, use Lovejoy Flexible Couplings.

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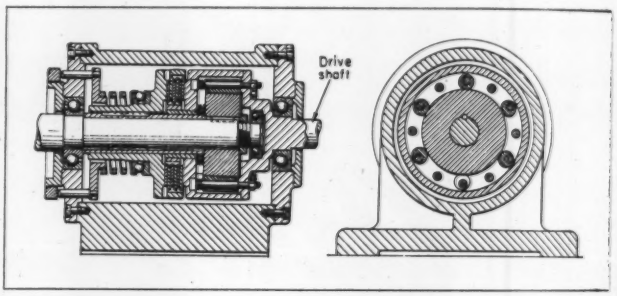
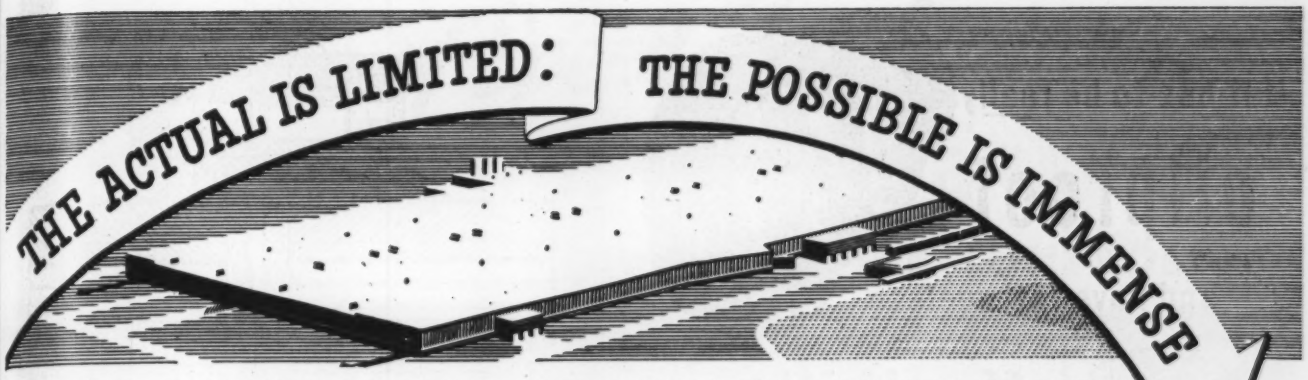
NOTEWORTHY Patents

OVERRUNNING of the driven shaft of a friction clutch is prevented with eccentric rollers which lock drive and driven shafts together when the latter starts to overrun. Normal starting and acceleration of the output shaft is through a spring-loaded friction disk clutch. Sudden deceleration of the drive



shaft, together with inertia of the driven shaft, would ordinarily cause these friction disks to slip. When the output shaft starts to overrun, the eccentric rollers lock the drive shaft to the driven, causing the latter to decelerate at the same rate as the input shaft. Small torsion springs hold the eccentrics in light contact with the cylindrical surface on the driven shaft member at all times, assisting in causing the locking action when the overrun starts. The patent, No. 2,554,305, has been assigned to C. B. Cottrell & Sons Co. by Hans J. Luehrs.

TORQUE-RESPONSIVE COUPLING which automatically re-engages at a predetermined lower speed is covered in patent 2,546,633, granted to Adiel Y. Dodge. Radial plungers in the input half of the coupling are forced into notches in the output half by spring-loaded axially-moving fingers which act on the beveled outer ends of the plungers. Sides of the notches in the output half of the couplings are tapered to provide cam surfaces which act with the inner ends of the radial plungers. When the maximum design torque of the coupling is exceeded, the slanted sides of the notches force the plungers out of the notches against the spring pressure of the fingers, disengaging the two clutch halves. A hydraulic check mechanism prevents immediate high-speed re-engagement of the clutch; when the radial plungers are displaced outward by the overload, oil trapped above the plungers is directed to several small cylinders equipped with pistons and check valves. The clutch cannot re-engage until ball checks controlled by centrifugal weights on the input half of the coupling permit oil



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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STEEL DESIGN SAVES MATERIALS AND MAN-HOURS ... CUTS COST 60%

WHEN a design utilizes the economies of welded steel, it can be produced for less cost because:

With welded steel, material costs are less. Only 50% to 25% as much metal is required. And, pound for pound, steel costs 75% less, giving an initial 7-to-1 cost benefit with which to start your designs.

With welded steel, fewer man-hours are needed for fabrication regardless of quantity produced. Smaller lots can be manufactured economically using simple tools. As quantities increase, designs can be modified further to replace some welding with bending, thus further reducing production costs.

Wherever costs with steel designs are higher, invariably the designs have fallen short of achieving the ultimate in savings possible with arc welding, or the products have been "over-designed." A restudy of every design by production engineers, before it becomes "frozen" for manufacture, helps eliminate costly details.

Your Lincoln Welding Engineer will gladly assist in analyzing your product requirements to cut costs.

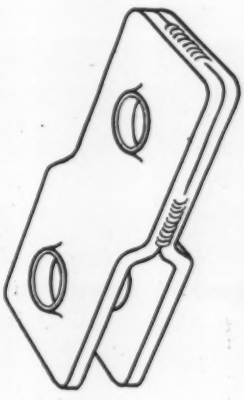

Fig. 5—Steel Stamping *from light gauge metal is formed in a die and welded. Weight is cut to 2 pounds . . . cost to 22¢ . . . a saving of 62% over Fig. 2. Saves 85% over Fig. 1.*

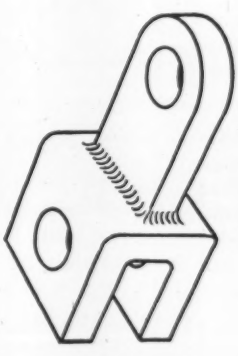

Fig. 4—Saves 16% Cost *over Fig. 2 by replacing tubing with simple "U" formed from bent steel strap. Holes are prepunched prior to welding. Weighs 2½ pounds . . . costs 49¢.*

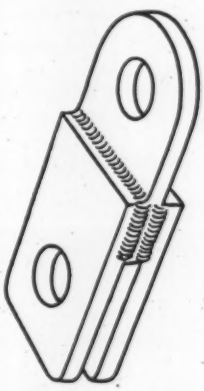

Fig. 3—Uses Sheared Steel Strip *to cut 10% from production costs, as compared with Fig. 2. Requires only simplest of fabricating equipment. Weighs 3 pounds . . . costs 54¢.*

the ACTUAL

Fig. 1—Original Design. *Machine clevis weighs 7 pounds . . . requires drilling, boring, reaming and spotfacing operations. Costs $1.45 for material and labor.*

increasing the YIELD

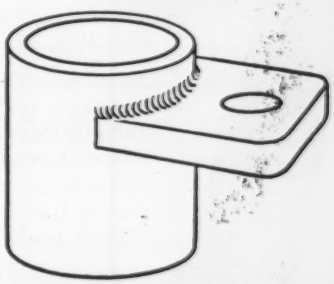

Fig. 2—Welded Design Saves 60% Cost. *Fabricated from tubing and steel strap. Needs only fast, simple punching operation. Weighs 3¼ pounds . . . costs only 98¢.*

the IMMENSITY of the POSSIBLE

Lower Costs Regardless of Quantity Produced

SEE HOW STEEL DESIGN CUTS COSTS STILL FURTHER

Machine Design Studies are available to designers and production men. Write on your letterhead to Dept. 19,

THE LINCOLN ELECTRIC COMPANY

CLEVELAND 1, OHIO

If it has to be really

oilproof

and have fatigueless

flexibility...

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RESISTOFLEX

HOSE ASSEMBLIES

There's nothing to fatigue in Resistoflex hose—not the synthetic rubber jacket, the high grade yarn braiding, nor the compar tube.

And no gumming, eroding or swelling from oil either. For the compar tube is impervious to water-insoluble oils and compounds. The compar tube also adds more than necessary strength for medium pressures and shock loads in hydraulic systems.

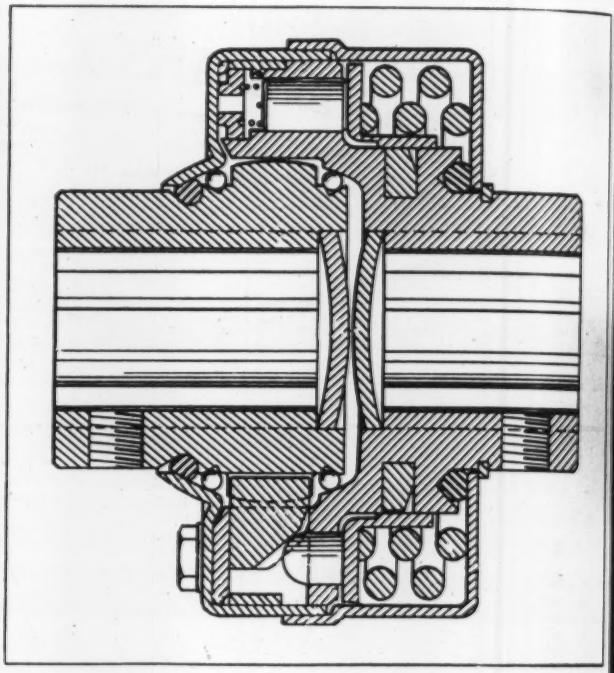
For years, many well known companies have standardized on Resistoflex Hose Assemblies to assure minimum line troubles and replacements. You, too, will find that Resistoflex quality pays off in the long run. Write for specification sheets.

For out of the ordinary engineering with synthetics

RESISTOFLEX

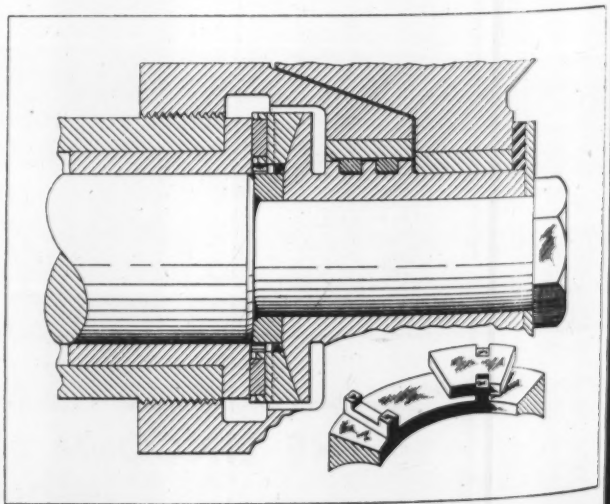
CORPORATION

Belleville 9, New Jersey



to bleed back to the space above the radial plungers. This check valve arrangement prevents contact between the plungers and the notches while the driving half of the clutch is overrunning at high speed.

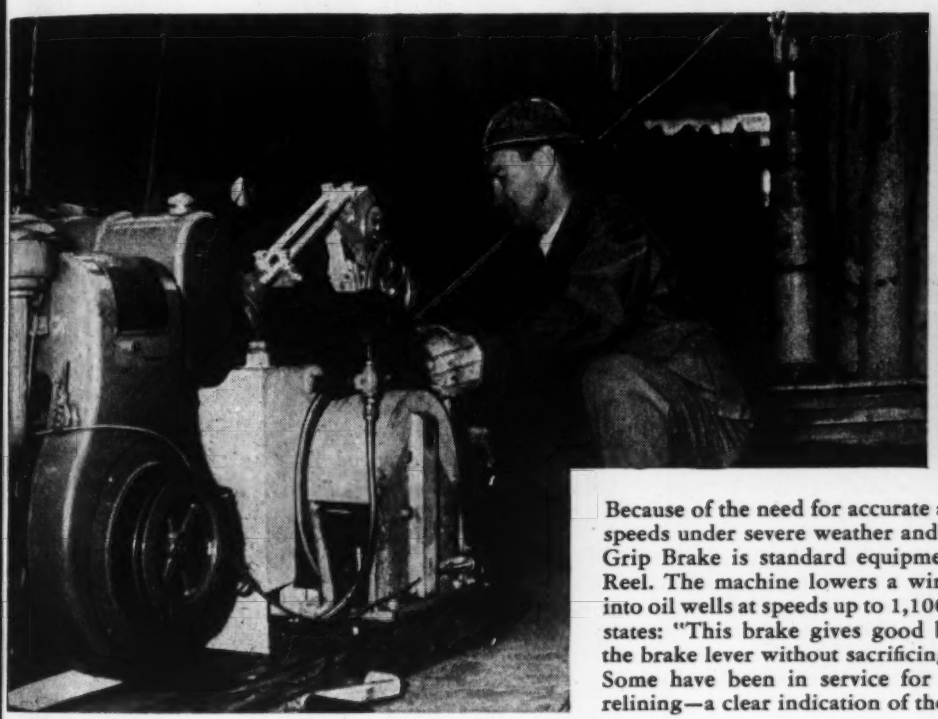
SMALLER PIVOTED-SHOE THRUST BEARINGS than is practical with conventional construction is covered in patent 2,558,262. Proven in sizes down to 1¼ inches outer race diameter, the bearings employ a spherical seat secured to a stationary center shaft. The mating spherical bearing race carries slippers on its back face which bear against the thrust surface of the rotating hollow load shaft. Slippers are held on the back surface of the spherical race by posts which fit into notches on two edges of the slippers, the backs of the slippers rocking or tilting on bars located at an off-center position so that one end of the slipper tends to swing away from the race. This end is made the leading edge with respect to shaft rotation, so the tendency to swing away from the shaft



A Problem of Speed Plus Accuracy—

SMOOTH, RESPONSIVE BRAKES

GIVE POSITIVE CONTROL!



Because of the need for accurate and dependable control of rotation speeds under severe weather and working conditions, a TDA Duo-Grip Brake is standard equipment on the Halliburton Measuring Reel. The machine lowers a wire measuring line and instruments into oil wells at speeds up to 1,100 feet per minute. The manufacturer states: "This brake gives good braking effect with little effort on the brake lever without sacrificing sensitivity and accurate control." Some have been in service for three and one-half years without relining—a clear indication of their excellent performance!

WHATEVER *YOUR* BRAKING PROBLEM— TAKE IT TO TDA BRAKE DIVISION!

It's hard to think of a more important factor of machine operation than *control.* When the rotation of equipment must be retarded for a time—or brought to a full stop—this matter of control becomes a task for efficient, properly designed brakes. That is why more and more machine manufacturers are turning to TDA Brake Division. Backed by more than 40 years of concentrated experience in the field, thoroughly qualified specialists are available to analyze your brake needs and to supply equipment precisely engineered for your specific purposes. TDA Brakes can improve your product's performance and reduce your customer's maintenance expense. Mail the coupon below—*today!*

Here Are A Few Of The Many Products Which Can Be Equipped With TDA Brakes

Centrifuges • Compressors • Conveyers • Cranes Cream Separators • Diesel hook-ups • Dry cleaning machinery • Extractors • Hoists • Industrial electric trucks • Lathes (automatic) • Looms (textile) • Lumber mill machinery • Machine tools • Materials handling equipment • Motors • Packaging machinery • Paint mixers • Press brakes • Printing presses • Rolling mills • Shears • Warpers (textile) • Welding positioners • Winches • Automotive • Farm equipment Earth moving equipment • Construction equipment Public transportation

IF IT ROTATES WE CAN BRAKE IT

TDA BRAKE DIVISION—DEPT. B-1
ASHTABULA, OHIO

Please mail brake information on these applications.

NAME_____

COMPANY_____

ADDRESS_____

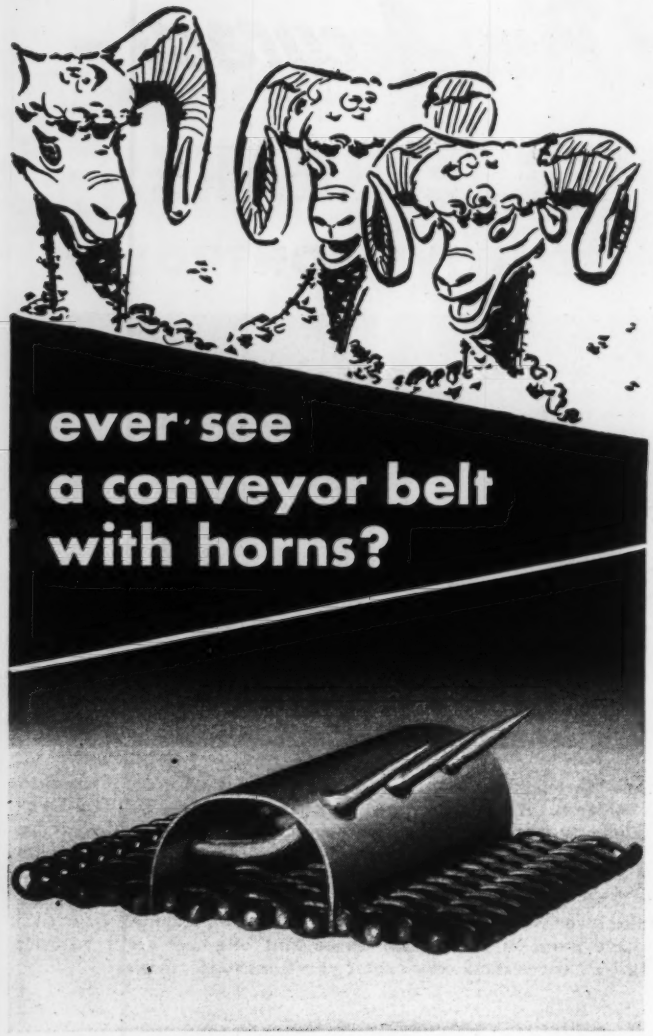
CITY_____ STATE_____

TIMKEN *Detroit* BRAKES

TDA BRAKE DIVISION
THE TIMKEN-DETROIT AXLE COMPANY
ASHTABULA, OHIO

Accepted TDA *Standard*

TRADE MARK REGISTERED



Textile processors will recognize this unique belt as part of a Bale Breaker . . . the device that rips apart bales of raw fibre for processing. Heretofore, it has consisted of a series of steel spikes mounted on canvas belting. However, the spikes often strike stones, bits of metal or other foreign objects inside the bale, causing sparks that ignite flash fires that burn the belt itself.

Cambridge design engineers solved this problem by attaching metal spikes to a standard *woven wire* conveyor belt. Results: fewer fires because Monel metal spikes reduce sparking, no belt damage or repairs when fires do occur, water from sprinklers will not harm the belt, longer belt life from all-metal construction.

This is a typical example of the many unusual or difficult problems solved by the use of Cambridge woven wire conveyor belts. Cambridge belts can be constructed from any metal or alloy in a wide range of open or closed weaves. For any problem of combining product movement with processing through heat, cold or corrosive agents, rely on the experienced advice of your Cambridge Field Engineer. Write direct or see "Belting-Mechanical" in your Classified Telephone Directory.

The Cambridge Wire Cloth Co.
Dept. N • Cambridge 10, Md.

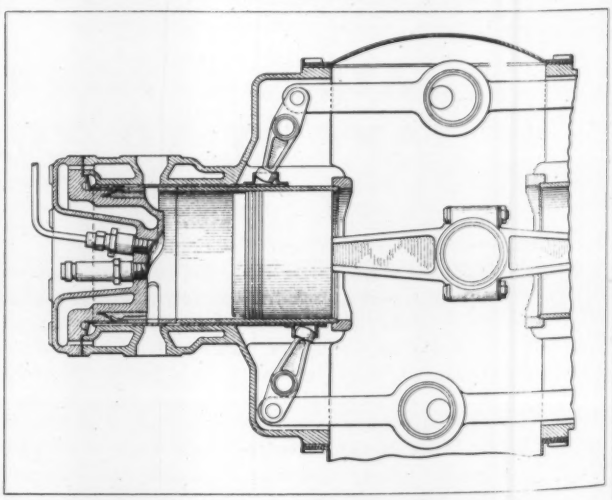
See us at the Metal Show BOOTH C-111

FREE CATALOG gives belt specifications, construction features, engineering data and conveyor design for many plants including food, ceramic, chemical, metalworking and others. WRITE TODAY FOR YOUR COPY of this valuable reference.

helps to establish the oil film. This bearing construction is unique in that precise machining is required on only three surfaces: the supporting edges of the tilting bars, and the two opposite surfaces of the slippers. Since these surfaces are readily adapted to close tolerance work, the bearing is especially suited for the smaller sizes. C. R. Maxwell and R. V. Larson have assigned the patent to Caterpillar Tractor Co.

HOLLOW-CENTERED V-BELTS, with an open slot leading to the outside, are claimed to run cooler and relieve the internal stresses caused by compression and flexing while in the sheaves. The continuous pumping action generated by alternate opening and closing of the slot leading from the center to the outside maintains a constant circulation of air. Squeezing of the section of belt in the sheave merely causes deformation of the center hole without raising serious compressive stresses. The patent, No. 2,540,245, has been granted to C. W. Dean.

INDEPENDENT SLEEVE VALVES permit increased horsepower capacity of internal combustion engines because of higher permissible speeds. Instead of utilizing the reciprocating piston to open and close the air intake port and a single sleeve valve for the exhaust port, the engine covered in patent 2,516,325, granted to Walter Kasten and assigned to Skinner Motors Inc., uses separate sliding sleeves for intake

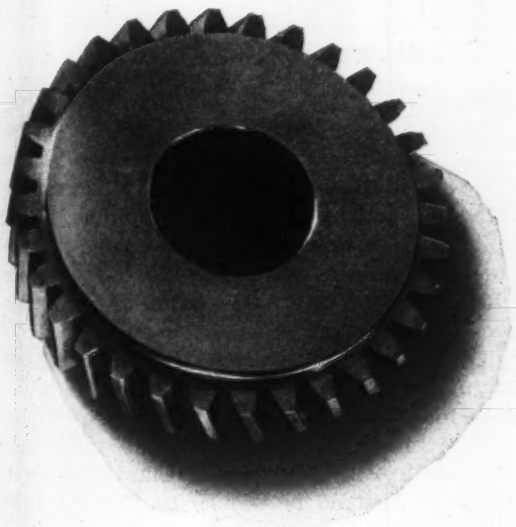


and exhaust ports, permitting variation in timing and duration of both ports in relation to piston travel. Also to provide improved scavenging, the air baffle is located on the cylinder head near the air inlet rather than on the piston head. The sleeve valves can be driven either at crankshaft speed or at one half crankshaft speed.

Complete printed copies of all patents are available from the Commissioner of Patents, Washington 25, D. C., for 25 cents each.

Kodak Conju-Gage Gear Checkers deliver

A fundamental improvement in quality control of gearing

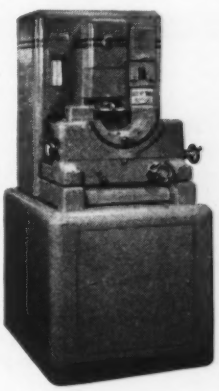


RESULTS—toolroom precision... versatility... fast checking... no questionable rejection losses

Gear manufacturers and engineers are meeting the requirements for increased production of tighter and tighter tolerance gears with improved precision manufacturing equipment. Invaluable in quickly checking and controlling the quality of this tight-tolerance production are Kodak Conju-Gage Gear Checkers.

The fundamental principle around which Kodak Conju-Gage Gear Checkers are designed is a new kind of gaging element—the Kodak Conju-Gage Worm Section—inherently simple and accurate in form—made to tolerances almost impossible to obtain in circular master gears, especially in finer pitches.

A single Kodak Conju-Gage Worm Section of given normal pitch and pressure angle checks any corresponding spur or helical gear of any helix angle. It checks the composite effect of runout, base pitch error, tooth thickness variation, profile error, and lateral runout, as recommended in the new American Standard.* Lead error, crown, and taper can also be checked and applied to standard quality control inspection procedures.



Kodak Conju-Gage Gear Checker, Model 4U, tests gears up to 4⅛″ pitch diameter. Automatically writes records to ship with gears or to hold for reference. Larger and smaller models are also available.

Anyone interested in the fundamental improvement of quality control of gearing will find the booklet, "Kodak Conju-Gage Gear Testing Principle," extremely helpful. It's yours for the asking. Eastman Kodak Company, Industrial Optical Sales Division, Rochester 4, N. Y.

*To those interested, we shall be happy to present, with our compliments, a copy of the new American Standard, "Inspection of Fine-Pitch Gears" (AGMA 236.03, ASA B6.11-1951).

CONJU-GAGE INSTRUMENTATION

...a new way to check gear precision in action

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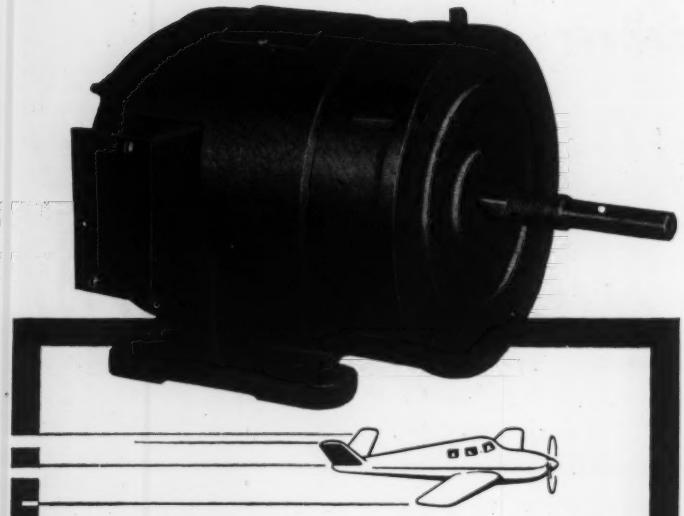

Your Peerless Electric Motor Department can serve you promptly

ONE of the finest motor engineering staffs can be your motor department when you call on Peerless Electric.

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Single Phase • Polyphase • Direct Current • ¼ to 15 H.P.

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PROFESSIONAL Viewpoints

". . . disagree in certain details"

To The Editor:

I have just had an opportunity to review the article "Engineering for Producibility" from the August 1951 issue of MACHINE DESIGN. It is an extremely well-thought-out article, and in my opinion should be in the hands of all executives responsible for production and design. In fact, with your permission, I would like to quote extensively from it in publications to members of our Society.

I disagree with the author only in certain details contained in the article, one of which is TABLE 1 giving "Machinability Ratings of Metals and Processes." For example, cast iron, (soft) is given an 80 per cent rating but is included in "Class 2. Ferrous (50% to 60%)" instead of "Class 1. Ferrous (70% and higher)" where it belongs.

Machinability Values Questioned

I also feel that Professor Boston's values, determined some years ago, are not typical as concerns the comparative machinability of cast iron and malleable iron. I do not know how these apparently anomalous values arose, although I recall discussing the subject with Professor Boston and his recommending that a project be undertaken to check some of the figures on cast iron. One of the obvious inconsistencies in this table is that a soft cast iron is shown to have a lower machinability rating than a pearlitic malleable iron. This is contrary to all industrial experience, and in discussions with Carl F. Joseph, technical director of the Central Foundry Division of General Motors, he stated that there was no question that a soft gray iron was superior in machinability to even a standard fully-annealed malleable iron, much less the harder pearlitic malleables. Since the company produces both malleable and standard gray iron (cast iron) components on which extensive machining operations are necessary, I believe his judgment must be accepted. Along this same line, you may be interested to know that the Gray Iron Research Institute recently reported that they have found that gray iron, as opposed to other metals, can be frequently rough and finished machined in a single cutting operation.

I realize, since this reference was made directly from the tables in the *Metals Handbook*, that only the sources can be criticized. I thought you would, however, be interested in these observations.

—C. O. BURGESS
Technical Director
Gray Iron Founders' Society Inc.
Cleveland

DAYTON COG-BELTS* put teeth in your drives

- DELIVER 40% MORE H. P.
- SAVE 28% DRIVE WEIGHT
- SAVE 47% DRIVE SPACE

40% more efficient than ordinary V-Belts, Dayton Cog-Belts actually let you *save* on drive cost, while *improving* the performance of your V-belt driven product!

Here's an actual example of how 5 replaces 7 in V-Belt power transmission. Take a 40 h.p. drive requiring C section belts. To do the job you need 7 V-belts. But because each Cog-Belt delivers 40% more h.p., you need only 5 Cogs!

With fewer belts, your drive weighs 28% less, takes up 47% less space, saves on shipping, handling, warehousing. Moreover, through the years your product *stays* sold, trouble-free.

How come? Cog's exclusive, patented, built-to-bend design (the fundamentally "right" design for a V-belt), and premium construction from electronically processed rayon cords make them stronger. They can stand flexing strains, starting and shock loads, better. They last years longer. To cut product costs —write for bulletin of engineering data on the Cog-Belt.

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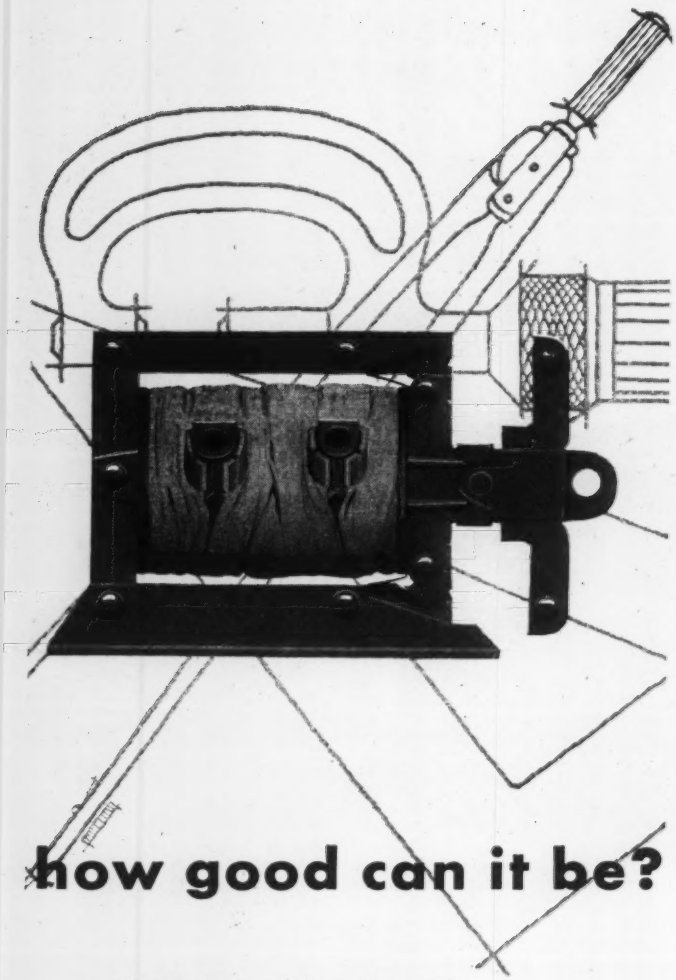
V-Belts by **Dayton Rubber**

*T.M.

WORLD'S LARGEST MANUFACTURER OF V-BELTS



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In the design, engineering and manufacture of electrical specialties, the guiding principle at Soreng is *How good can it be?*

"Good enough" is never good enough. Our designers, research and development engineers, our production specialists—all are constantly working to make Soreng products better than ever.

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Metallizing

(*Continued from Page* 144).

well-defined shadow. These methods are used principally in the batch coating process. Another method of preventing the evaporated metal from depositing is to print the area which is not to be metallized with a thin film of grease. The grease evaporates during the coating process, producing a local, high-pressure vapor concentration immediately above the printed area, which reflects away the metal particles. This technique is particularly valuable in connection with continuous evaporation processing.

For example, in the production of a certain condenser from metallized paper, long narrow strips one inch wide with an unmetallized margin ⅛-inch on one side is needed. It is cheaper to metallize wide rolls of paper rather than 1⅛-inch strips. The desired product can be made by printing a ¼-inch wide greased strip along the length of the roll with a roller inside the vacuum chamber just before the sheet is exposed to the metal vapor. By spacing these strips properly, the master roll will have alternate areas ¼-inch wide unmetallized and 2 inches wide metallized across the width of the sheet. The master roll is then slit in the center of each metallized and each unmetallized strip, giving a number of rolls 1⅛ inches wide with a ⅛-inch margin on one edge.

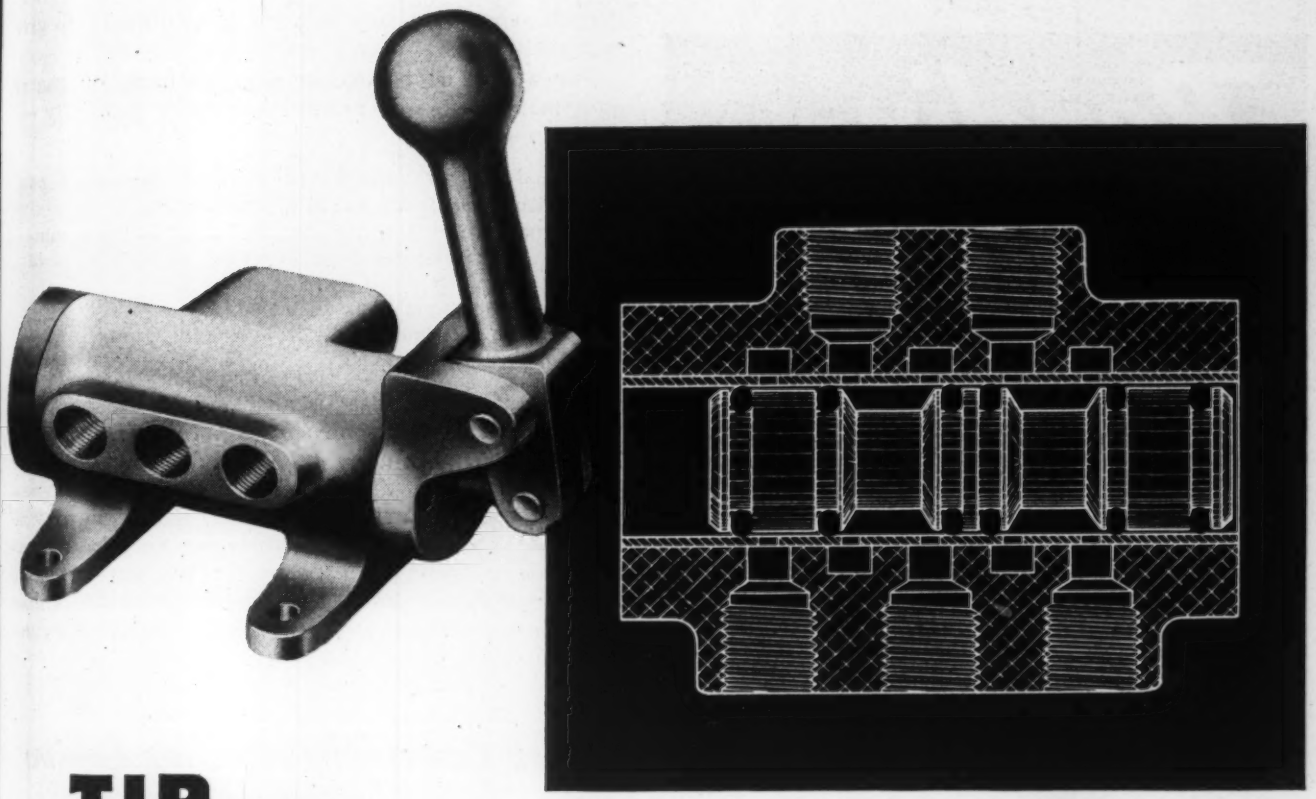
Stripping Used for Condensers

Condenser paper metallized with zinc is made by this technique. Paper metallized with aluminum, however, is made by metallizing the entire sheet and then removing metal from the areas in which it is not wanted. This is accomplished by passing the metallized paper over a number of narrow metal rollers placed at the proper spacing across the width of the sheet. A high voltage source is connected between the metallized paper and small rollers. The high current density at the points of contact under the small rollers arcs off the metal, clearing the paper of the evaporated aluminum coating in narrow strips the width of the rollers. The master roll of metallized condenser paper is then slit as required.

COST AND PRODUCTION RATES: A batch evaporator 48 inches in diameter would involve costs as shown in the following along with production rates:

Equipment cost: $15,000 to $25,000 depending on complexity of jigs, etc.
Cycles per hour: 2 to 3 depending on size and nature of load.
Size of load: Type *Fig.* 2—up to 45 sq ft: Plexiglass sheets, horn buttons. Type *Fig.* 3—up to 6000 small ornaments.
Labor to run: One man.
Current cost: $1.00 per load.
Filaments, etc.: 10c to $1.00 depending on type of evaporation (*Figs.* 2 or 3).

Since total costs should include items like amortization, overhead, per cent of spoilage or rejects, special jigs, labor on loading jigs, inspection, pack-



TIP...

FOR DESIGNERS

Forty Million Cycles Without Wear Using...

LINEAR "O" RINGS

Think of it! Forty million cycles—*eighty* million strokes—and still no sign of wear in a Modernair CV Series pilot valve using six Linear "O" Rings as a sliding seal between cylinder and piston.

This was no laboratory set-up. This example of outstanding service from Linear "O" Rings was reported by the Victor Equipment Company, users of Modernair control valves.

Trouble-free service measured in scores of millions of cycles is only one advantage credited to Linear "O" Rings. When wear finally does become evident, the valve is *completely renewed* simply by installing new Linear "O" Rings. Elimination of metal-to-metal contact makes possible the use of easily machined aluminum instead of cast iron or steel. This means low fabricating costs and light, compact construction.

Linear "O" Rings are compounded of natural or synthetic rubber, fluorethylene polymers, and "Silastics" . . . are molded in a complete range of J.I.C. and A.N. standard sizes, as well as hundreds of non-standard sizes and special shapes. Precision molded under rigid laboratory control, Linear "O" Rings may be depended upon for continuous and lasting service.

It will pay you to consult Linear during the design stages of your sealing applications.

"PERFECTLY ENGINEERED PACKINGS"

LINEAR

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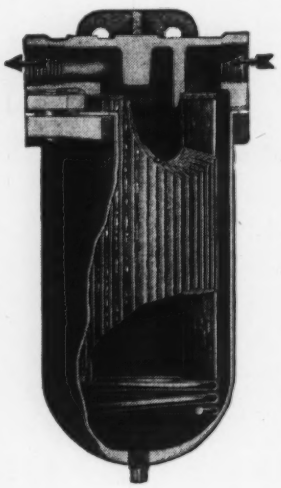
ORIGINATOR OF **MICRONIC** FILTRATION

Results Prove It

the *Finest*

Name in Filtering

Nine times out of ten ***Bendix-Skinner*** Filters will supply the "finest" answer to your filtration problems. Here are the facts: available with patented, exclusive, resin impregnated cellulose elements; simple, quick replacement; high flow rate with minimum pressure loss; no channeling or bypassing; over 350 models providing filtration from ½ micron (.000019") upwards at flow rates from 1 to 5000 g.p.m. Why not let ***Bendix-Skinner*** filtration engineers work with you? Write us direct.



Model 3110-P filter element, 6⅛" x 3½", has a filtering area of 940 sq. in.!

Disc-type Ribbon-type Pleated-type

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1503 TROMBLY AVENUE,
DETROIT 11, MICHIGAN

Bendix AVIATION CORPORATION

Export Sales: Bendix International Division, 72 Fifth Ave., N. Y. 11, N. Y.

ing, shipping, sales expense, etc., it is difficult to give complete costs.

For a continuous evaporator, including outgasing equipment, costs and production can be generally expected to run:

Equipment cost: $60,000 to $100,000 depending on width of material, rate of production, etc.
Coating rate with aluminum: 25 to 125 feet per minute depending on type of material, thickness of coat, etc.
Current: $6.00 per hour.
Crucibles, aluminum, etc.: $6.00 per roll.
Labor to run: Two men.

Vacuum coating has become one of the standard methods considered by design engineers to coat products which require a metallic finish. It has made the production of many new products possible and new applications are increasing rapidly. Designers who feel that vacuum coating may improve product appearance and acceptance should investigate vacuum coating to determine if this process is better suited to their requirements and if the end result provides a better product at a lower cost.

Most Powerful Propeller Engine

DEVELOPING more power for its weight than any propeller type engine ever cleared for flight anywhere in the world, the new Allison T 40 turbo-prop engine is rated at 5500 hp. This is more than two horsepower for each pound of engine weight, including extension shafts and the reduction gear, comparing with roughly one horsepower per pound of weight for the best piston type engines of World War II. Fuel economy approaches that of those same reciprocating engines and is better than any turbine engine yet developed.

The new T 40 engine was developed under contract for the U. S. Navy. It is completely new design consisting of two axial-flow gas turbine power sections, each of which powers an extension shaft to a common reduction gear, which in turn drives contra-rotating propellers. The power sections are connected so they form a single unit. However, each power section may be operated independently. Inasmuch as the T 40 is a turbine engine, it uses the same low-grade, readily available fuel as turbo-jets, without the need for high-octane aviation gasoline. It is expected that specific fuel consumption will be reduced to 0.58 pounds per horsepower per hour.

Correction

In the article "Calculating Air Pressure Drop in Heat Exchanges" by R. E. Shafer on page 124 of the August issue of MACHINE DESIGN, density of the gas is represented by the letter r in the equations and by the symbol δ in the nomenclature. To be consistent, r in the equations should be changed to δ. This article was condensed by the editors from Mr. Shafer's original manuscript and the error occurred during this rewriting.

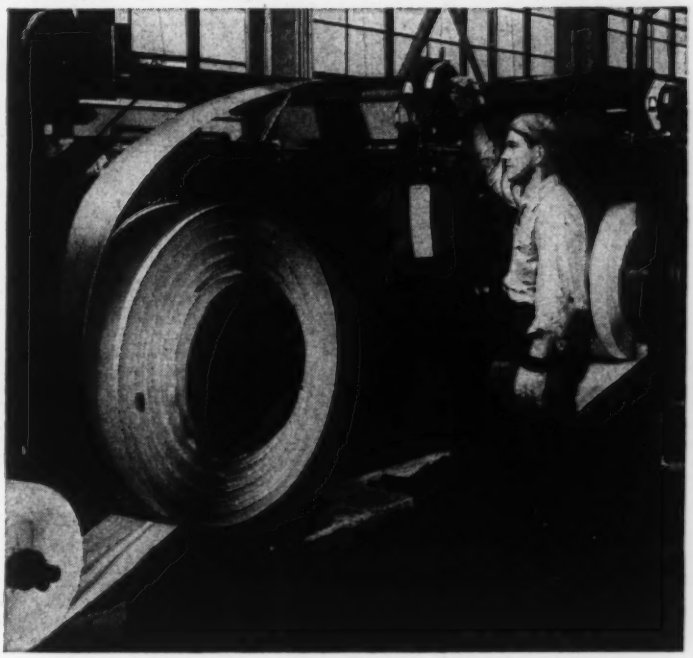
G-E ADJUSTABLE-SPEED DRIVE "SPOOLS" STRIP STEEL FASTER!

"Packaged" Speed Variators boost winder output by eliminating time-consuming tension adjustments

Without the proper drive on the winders, "spooling" chrome strip steel as it comes off an annealing line can be a difficult time-consuming operation. "Spool" build-up will vary with the gage of the steel being processed. This affects tension on the strip as it is being wound, making it necessary to make many time-wasting manual adjustments.

The Wallingford Steel Company overcame these difficulties recently when it installed seven G-E Speed Variators on its annealing line. Today, the winders operate automatically after an initial setting. The speed variators handle all operating speeds from 5 to 80 feet per minute. And because each drive is "packaged", it is simple to operate one, two, three or all of the winders in the line simultaneously.

The speed variator, one of G-E's adjustable-speed family, is helping manufacturers in every field to increase production with improved quality control, saving scarce materials, cutting rejects, and increasing versatility of existing machinery. There's a good chance that one or more of this versatile adjustable-speed drive family can do the same for you. Send the coupon below for complete details. *General Electric Company, Schenectady 5, N. Y.*



Once the operator makes a speed setting, the winder, equipped with a G-E Speed Variator Drive, maintains that speed automatically and holds tension constant during roll build-up.

WHICH DRIVES ARE BEST FOR YOU?

This 26-page manual will help you decide. It shows you how to go about selecting the *right* drive. The handy drive chart included is worth your detailed study. Bulletin GEA-5334. Check here. . . . . ☐

General Electric Company, Section H646-15
Schenectady 5, N. Y.

Please send me the bulletins checked:
☐ for reference only
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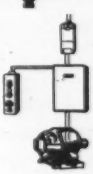

THE ACA MOTOR—*Speed ranges to 20:1*—An adjustable-speed a-c motor. Speed range 3:1 or 4:1 continuous; for intermittent operation from 6:1 to 20:1. Bulletin GEA-4883. Check here. . . . . ☐

THE SPEED VARIATOR—*Speed ranges to 40:1*—An adjustable-voltage d-c drive that uses a-c power. Speed ranges 8:1 to 40:1 and beyond. Bulletin GEA-5335. Check here. . . . . ☐

THY-MO-TROL*—*Speed ranges to 100:1*—The most accurate, most versatile, and fastest acting of all G-E adjustable-speed drives. Speed ranges of 100:1 or better. Bulletin GEA-5337. Check here. . . . . ☐

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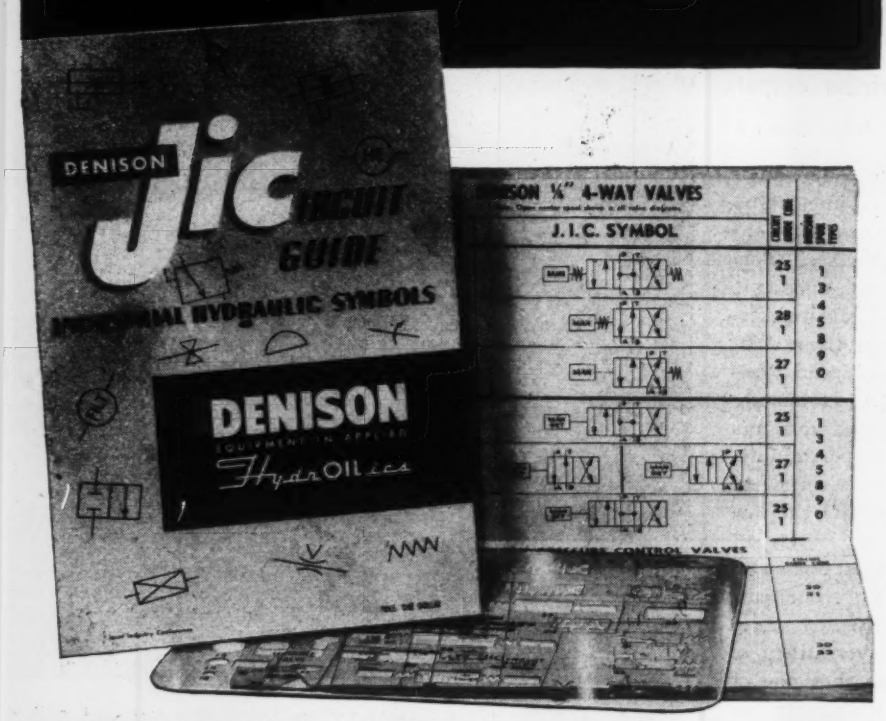

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DENISON Hydr OIL ics

Design Abstracts

(*Continued from Page* 146)

iron, which has a much higher tensile strength of 85,000 psi.

A food mixer motor gear assembly is shown in *Fig.* 1. A high-speed rotor (25,000 rpm) drives a molded nylon helical gear; this in turn drives a cut Textolite (plastic) helical gear which drives two other sintered-iron gears. These latter three gears all drive mixer beaters. As in other gear trains where plastic gears are used, the plastic is mainly for noise reduction.

In the application shown in *Fig.* 2, a worm gear drives a molded nylon helical gear which in turn drives a crank gear through the spur end of

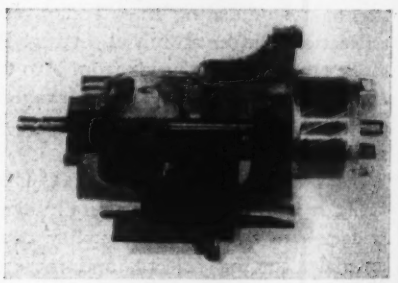

Fig. 2—Oscillating motion of a fan is accomplished by driving a sintered-iron crank gear with separately molded nylon spur and helical gears

the nylon gear. This mechanism gives the familiar oscillating motion to a 12-inch fan. The nylon spur gear and helical gear are molded separately. Standard (7 per cent Cu, balance Fe) sintered-iron material is used for the crank gear because it is the lowest-cost material which will do the job. These gears were originally cut from brass or steel but the change to sintered iron effected a saving of 65 per cent of the cost of the 12-inch fan gear.

An automatic washer gear train is shown in *Fig.* 3. In operation, a rotor shaft drives the dual gear through the helical teeth. The spur end of the dual gear drives the crank gear which, through the crank, moves the sector gear back and forth. This imparts a harmonic oscillating motion to the agitator pinion and consequently to the agitator in the clothes basket. These gears are all made from high-carbon copper-impregnated iron (1 per cent C, 15-20 per cent Cu, balance Fe).

Overall savings realized by changing from cut malleable-iron gears to impregnated sintered-iron gears exceeded 50 per cent. It is difficult to fix an exact figure since, with the

exception of the agitator pinion, these gears were never cut by efficient high-production methods. For the agitator-shaft pinion the saving was 60 per cent. Even with heavy loading, there is no report of any of these sintered gears failing in service.

Note that these sintered-iron gears are helical as pressed. In all other applications at GE spur gears are used or the helical teeth are cut. The helical gear is an unusual application of sintered iron because of the difficulty in molding helical teeth. This is a new design so there are no cost-reduction figures, but this gear could not be manufactured by any other process so economically. The material is standard sintered iron of the 35,000 psi type.

QUALITY CONTROL: One of the big problems in the use of powder metals is quality control. How can mechanical properties be tested? Since the structure is quite heterogeneous and inherently porous, hardness is not a good criterion. Only the finished part is available; there is no original stock to go back to for tensile strength, elongation, etc. As a

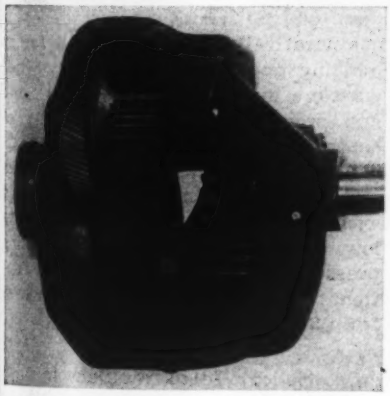

Fig. 3—Imparting a harmonic oscillating motion to the agitator of an automatic clothes washer, these gears are all made from copper-impregnated sintered-iron

result, the best method for testing quality is a destructive test of the part itself. With impregnated gears, the method we commonly use is to measure the shear strength of teeth in a tensile machine. This method of testing sintered-iron structural parts is suggested in ASTM Spec. B222-47T.

DIMENSIONAL ERRORS: Powder-metal gears are subject to certain dimensional manufacturing errors. Many are common to both conventional gears and sintered gears, although they arise from different sources. Others are unique in the powder-metal process.

In TABLE 1 the typical errors and tolerances of two conventional types of manufacture are compared to those

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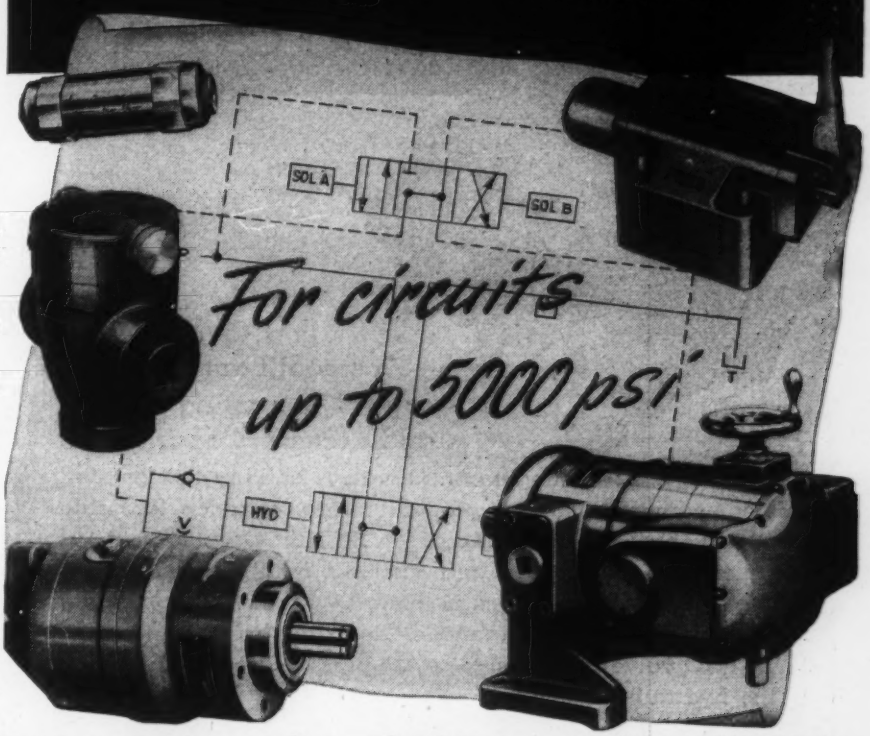

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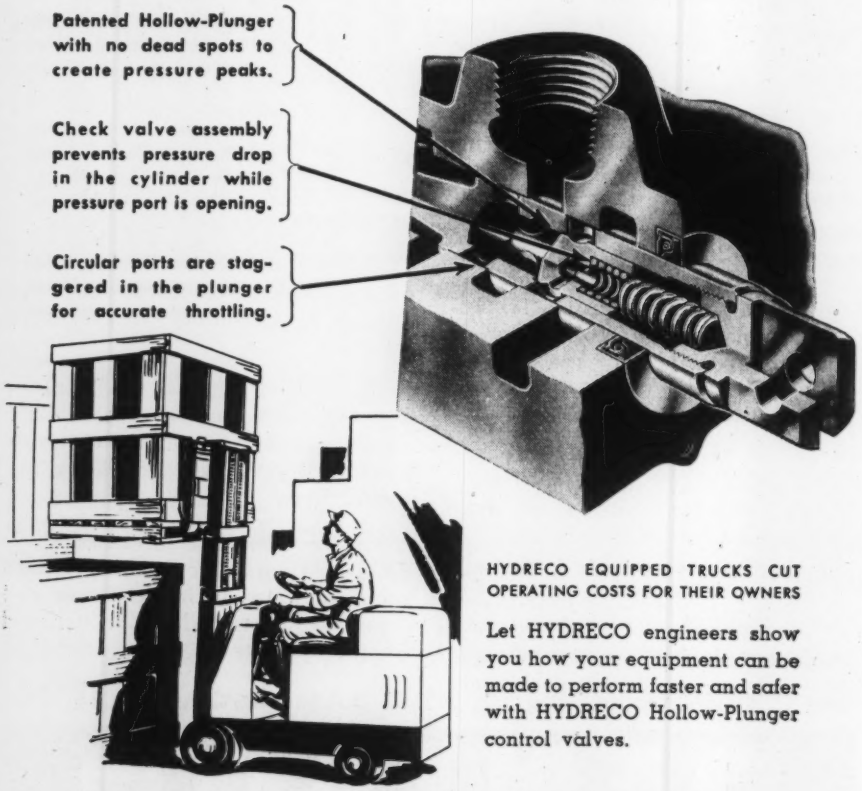

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of the powder-metal process, stamping and extruding.

SHAPE: The use of molding or briquetting tools limits the variety of shapes possible in powder-metal gears. Of course, subsequent machining or deforming operations are possible, but generally powder-metal gears are made in "single-draw" tools only (single pressure axis, no re-entrant surfaces). Face notches or interruptions can be molded in if they are not major masses. The maximum advantage occurs when a gear has an asymmetrical outline. Here the cost is usually ½ or 1/3 that of a cast or cut gear.

SIZE: The range of manufacturable sizes depends on strength of the tools (punches) in small sizes and capacity of the presses in large sizes. High-strength gears (85,000 psi) from 3/16-inch diameter to 3½ inch diameter have been made, the latter requiring a 300-ton press to briquette the green part. Web perforations would allow the same area to be enlarged to a greater pitch diameter. In medium and larger sizes about 30 tons per square inch exposed area are required for briquetting. Thickness of the blank (tooth face) is comparatively unimportant as far as molding goes; it counts mainly when warpage may distort the tooth flank and prevent adequate uniformity of contact. Thin blanks (less than 3/32-inch) are difficult to strip from the mold-in without injury to teeth, and excessively heavy sections may have low density because of briquetting pressure loss from excessive wall friction. Diametral pitches have varied from 32 to 10.

Helical Teeth Molded In

Teeth can be molded in the hub of a dual gear, *Figs.* 2 and 3, with optimum strength obtained by blending flanks and root with the hub for minimum stress concentration. Simple gears can be made with helical teeth molded in. Splines, keyways, and double-D bores can be molded in when an eccentricity of about 0.005-inch (total indicator reading) can be accepted. Round bores are frequently bored or ground with respect to the pitch line in a pin-chuck for optimum concentricity after sintering.

STRENGTH: Usual base materials are brass or iron. In the original first-sintered condition these metals have inherent strengths sufficient only for light-duty gearing such as timing devices, toys or small appliances. By suitable extra processes, these properties can be considerably increased.

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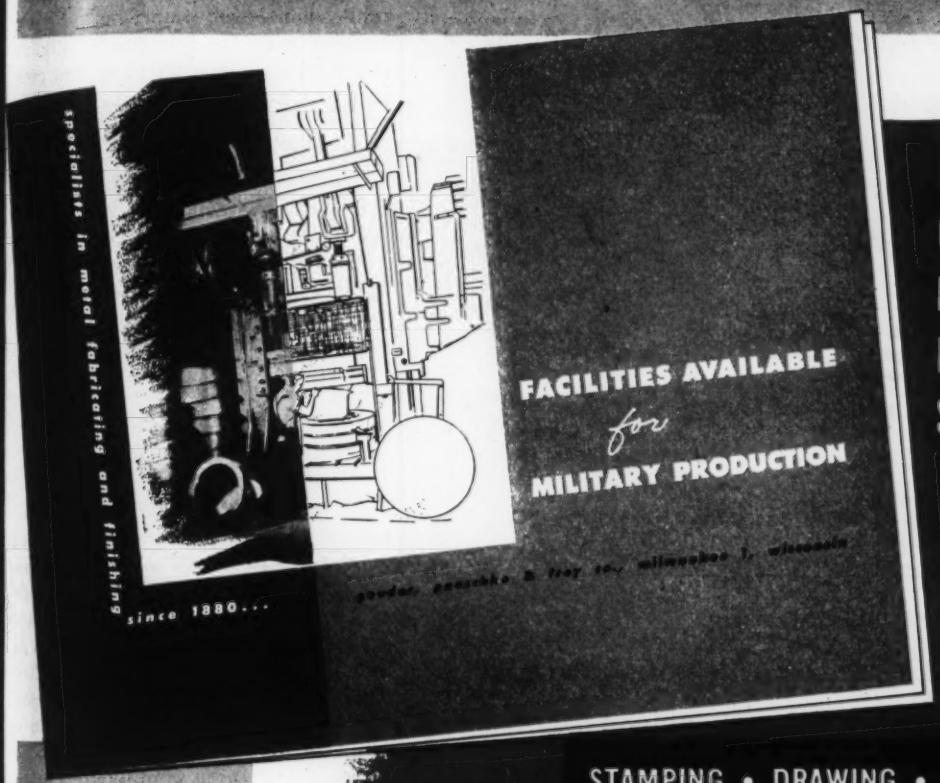

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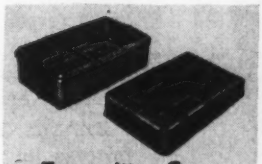
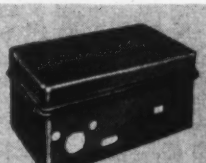

Transmitter Case and Cover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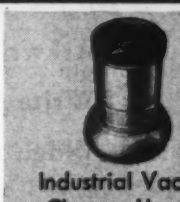
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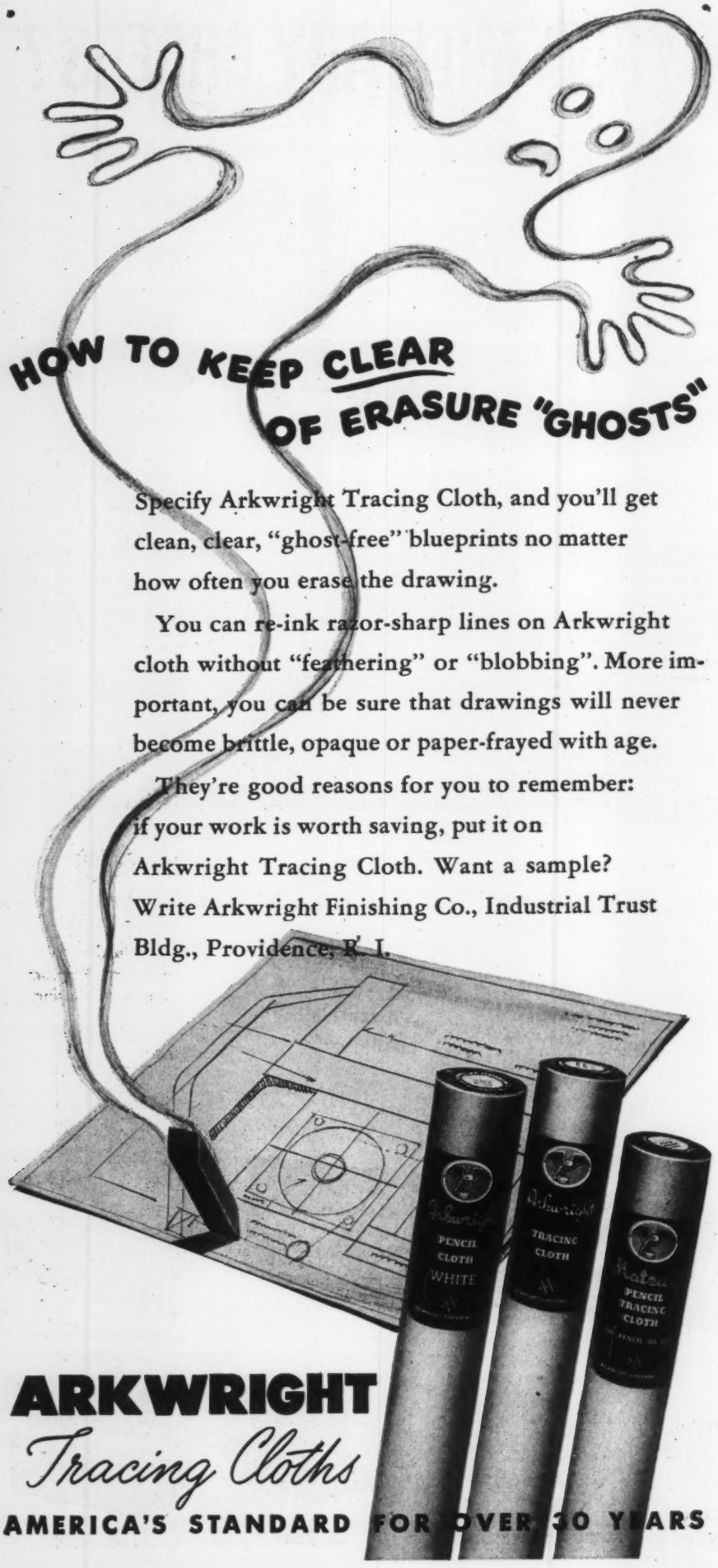


of strength. It has been observed that copper-impregnated gears are very good in this respect. Where substitute machined-steel gears wear and gall on a given washing-machine application, the impregnated gear polishes well, and wears negligibly. The heterogeneous surface, the presence of copper, and the slightly higher apparent hardness are thought to cause this.

LUBRICATION: For lightly loaded gears, the porosity of the sintered materials has been found to help self-lubrication. Initial oil impregnation, with or without a storage wick or reservoir, has been used. This assumes that face pores do not peen over and that the seepage path is not closed.

Quantity Costs Are Low

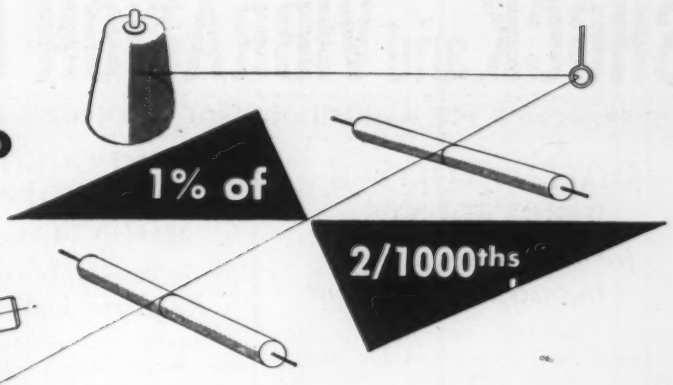
QUANTITY: The minimum economic quantity cannot arbitrarily be stated, but varies with the cost of competitive methods, performance advantages, consistency of quality, and availability. For a typical 1-inch diameter gear, tools might cost $2000. Thus, for a production run of 20,000, the tool component of cost would be ten cents per gear—which might be reasonable. For a complicated 3-inch diameter high-strength gear whose tool cost might be $10,000, a minimum run of 50,000 would make the cost of the dies not more than 20 cents per gear. Heavy-duty gears in these two sizes, in lots of 100,000, have been manufactured to sell at about 12 cents for the 1-inch size and 60 cents for the 3-inch size. Light-duty gears run as low as 2.5 cents.

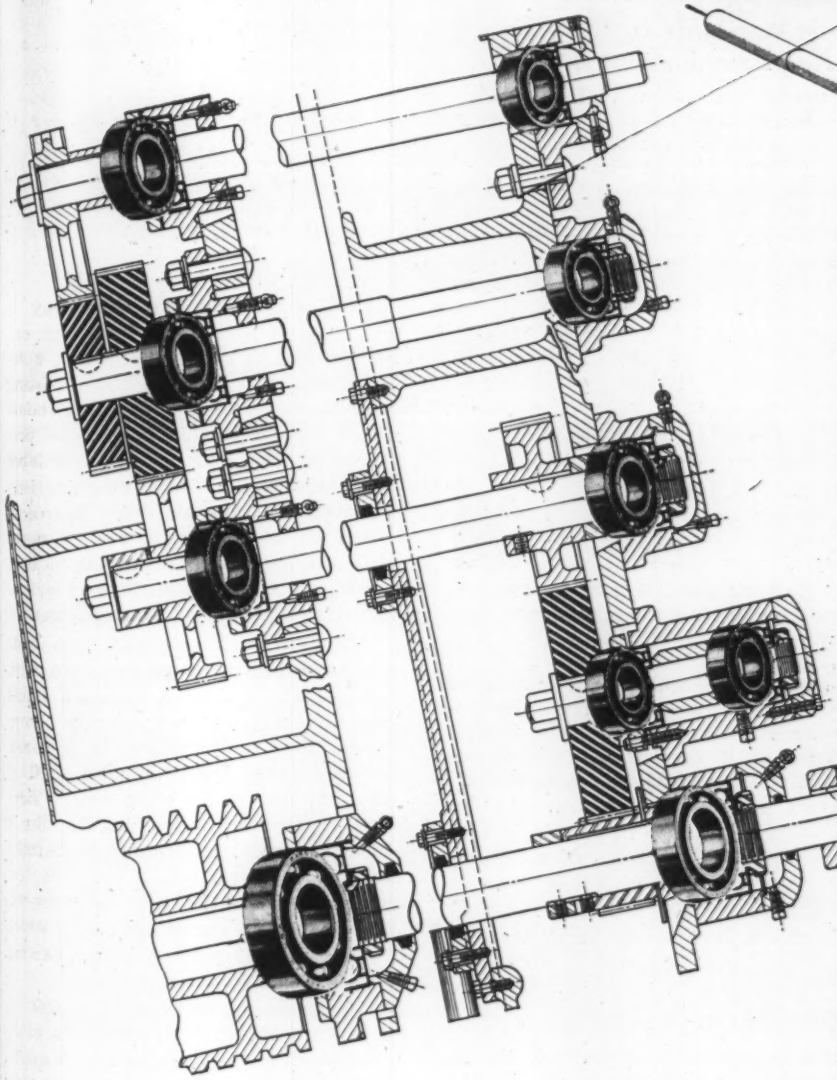
COSTS: The prime point of gain in powder-metal gears is the labor or time of tooth formation. In most cases the press can be set on automatic operation and sintering is done in a conveyorized furnace as are other treatments. There is almost no scrap loss in this process and as a result even the relatively high cost of most metal powders does not appear as a high piece price. Iron powder ranges in price from 10 cents to more than $1.00 per pound depending on purity.

SELECTIVE PROPERTIES: By powder-metal techniques some unusual results can be achieved. Selective impregnation of the teeth only, for instance, can be obtained. Further effects are possible, such as lamination of different powders, differences in porosity for special lubrication needs, and selective hardening to improve strength and abrasion resistance.

FINISH: Inherent in the molding process is the production of good tooth-surface finish. Tools are lapped to a mirror finish to minimize wall

SETUP
that holds tolerance to





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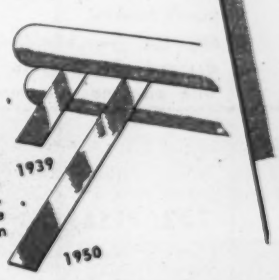

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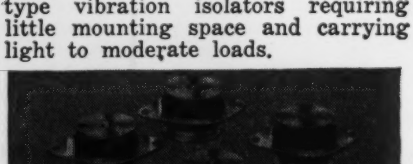

Unit mountings in this series can be furnished with load ratings as low as one pound and up to 11 pounds. The free height of the top of the unit mounting, above the central mounting plate, is approximately 23/64 inch. The symmetrical design permits loads to be applied either axially or radially, or with components in both directions.

Designed primarily as vibration isolators, the Series 6300 units have a transmissibility of about 6 at resonance, which occurs at approximately 15 cycles per second under rated load. Vibration isolation at 30 cycles or above is extremely efficient. The stability of the mounting is excellent, and transient shock isolation is satisfactory for the intended service.

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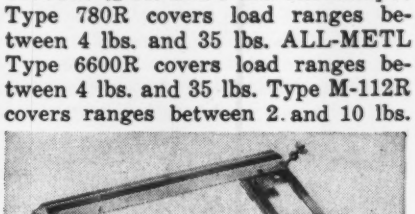

"Ruggedized" mounting bases, equipped with Barrymounts of the above types, are available in standard JAN sizes (JAN-C-172A) and in special sizes to meet customers' requirements. A conspicuous advantage of these "ruggedized" Barry bases is the gain in strength of the base framework itself — beyond JAN requirements — achieved with very little increase in weight for loads up to 60 lbs. by design modification of standard JAN bases. For greater loads, the "ruggedized" Barry bases are of stainless steel instead of aluminum. Write for data sheet.

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friction. The resulting gear teeth can be made smooth to a few microinches. Combinations of hobbing and shaving or grinding and lapping would otherwise be required.

From a paper entitled "Powder Metallurgy—A New Process for Manufacturing Gears," presented at the 35th Annual Meeting of the American Gear Manufacturers Association in Hot Springs, Va., June 4-6, 1951.

Casting Design

By C. T. Marek

Associate Professor
Purdue University
Lafayette, Ind.

BROADLY speaking, economy in casting production by design can be effected in two ways. First, a design should inherently avoid casting defects, and secondly, a casting should be so designed that it can be produced at the least expense of labor and materials. Two characteristic properties of metals must be recognized as underlying causes of many defects: shrinkage of metal in both the liquid and solid state, and lack of strength at elevated temperatures.

VOLUMETRIC SHRINKAGE: A mold cavity is like a container filled with hot liquid. Unlike a common liquid whose surface level merely drops when the temperature is lowered, molten metal forms a solid shell at the interface of the mold wall. Under this condition the casting is like a closed vessel containing a definite weight of metal which occupies less and less space as heat is removed. The result is a shrinkage cavity which occurs in that portion of the casting which is last to freeze.

To avoid a volumetric shrink in a casting, the foundryman must place feeders over those areas which solidify last. In order to make certain that the cavity appears in the feeder instead of the casting, the feeder must be of such size as to stay molten longer than the casting.

It is not uncommon to encounter designs with heavy sections located in mold positions which are difficult to feed or are inaccessible.

In order to produce a flawless casting under such a handicap, the foundryman must resort to artificial cooling. This is done with metal chills which may be inserted in the mold cavity and become part of the casting, or may be embedded in the mold to absorb and transfer heat from the casting more rapidly than is possible with ordinary mold material.

AVOIDING A VOLUMETRIC SHRINK: In spite of the feasibility of obtain-

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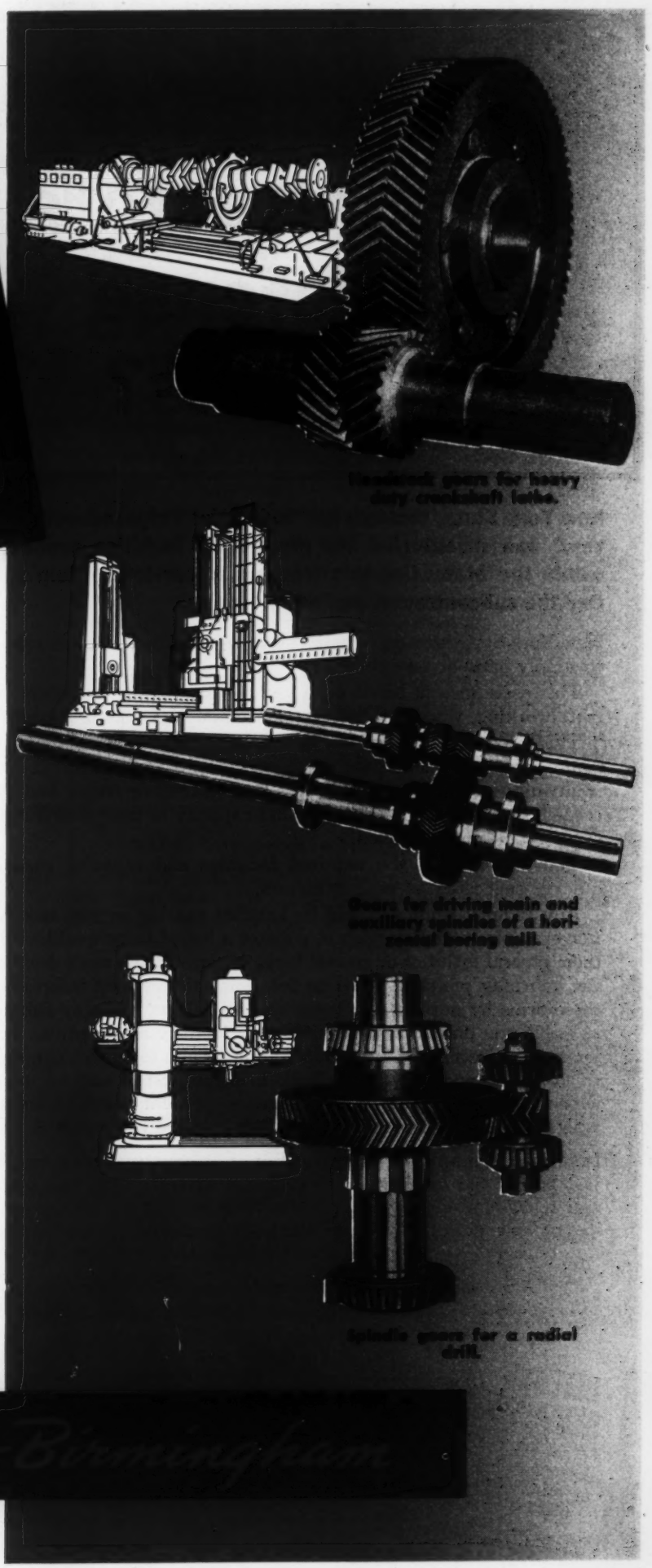
Farrel Gears



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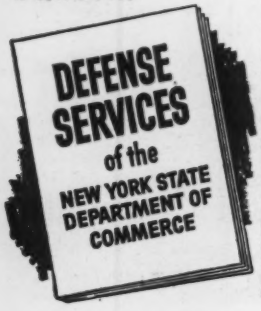

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ing sound castings by artificial cooling, there is no substitute for good design. An ideal design is one whose sectional thickness is least at points farthest away from the parting plane and gradually increases in thicknesses as the feeder is approached.

One of the prerequisites in avoiding a volumetric shrink by design is to know the location of the parting plane. Once this is established, the designer can proportion his casting to make it feasible for liquid metal to flow to the solidification front as it conveniently progresses toward the feed point.

Reducing Hot Spots

The engineer may reduce a hot spot by designing the casting so that a green sand core may be conveniently used, or he may have to resort to a more costly design which requires a dry sand core. Even when a dry sand core is needed, he may be able to design his casting to avoid expensive core boxes, core driers or excessive labor.

MASS EFFECT: Even when it is possible to feed a hot spot in a casting, a large mass of metal may be undesirable because of added weight, or because of the effect of the cooling rate on its mechanical properties. Although the relationship between rate of crystal growth and temperature change varies with different metals and alloys, the tendency to obtain a larger grain size with slower cooling rate is a common characteristic of cast metal. This results in softer metal of lower strength properties which may be undesirable for the design.

PROPERTIES OF METAL: The degree of adherence to ideal casting-design principles is dependent to a great extent on the casting properties of the metal. A casting which is designed with uniform sectional thickness throughout may be produced without much difficulty in gray iron; but if made out of steel or some other high-shrinkage metal it may turn out defective.

For example, a coarse dendritic structure was found in the center of a casting made of nickel-silver. The casting was 12 inches in diameter and 1 inch thick. Because of the lack of a desirable temperature gradient between the center and outer edge of the casting, flow of molten metal to the center was obstructed prematurely, causing a center-line shrink. After the top and bottom of the casting were machined, the casting was porous enough to leak when subjected to air or liquid pressure.

If correction by design were not permissible, the foundryman would have to produce this temperature

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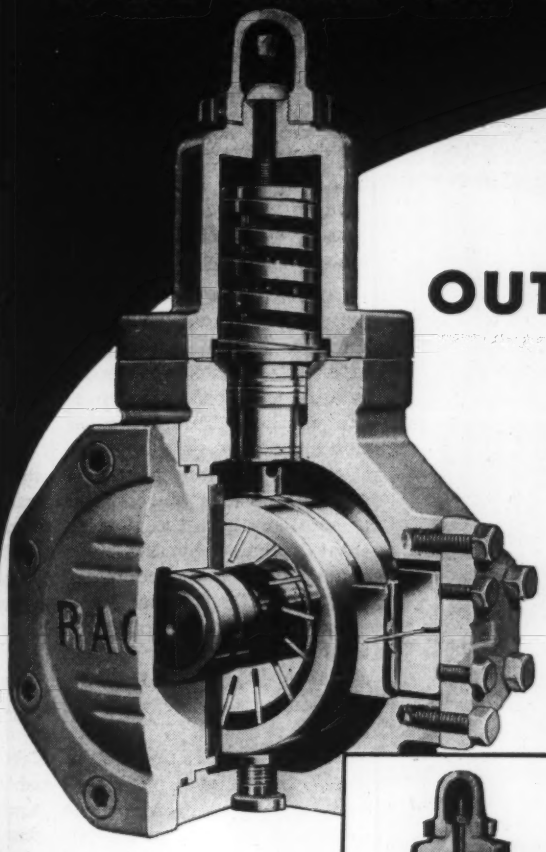

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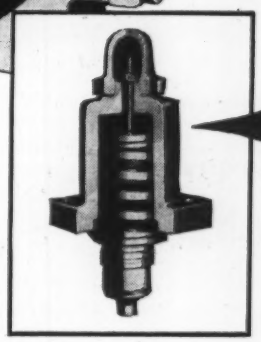
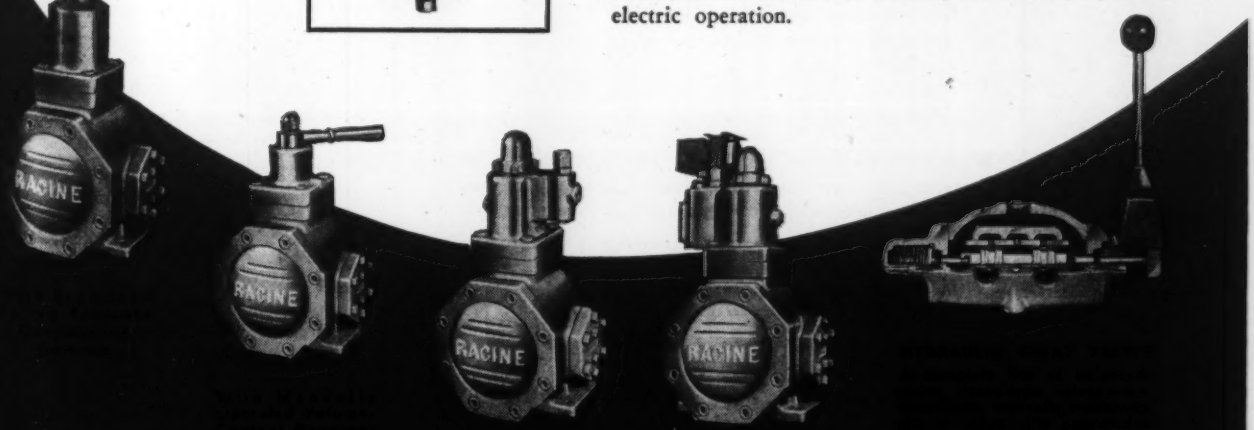


Interchangeable Governor Controls

At left is illustrated a standard pressure-compensating governor used in RACINE Pumps. Many other governors, some shown on the variable volume pumps illustrated below, are available for manual, mechanical, hydraulic or electric operation.



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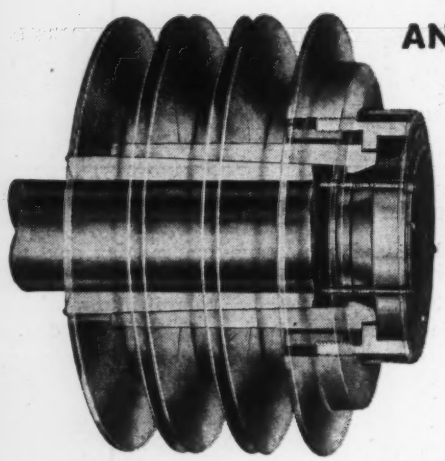

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gradient artificially. One way to do this would be to embed a chill in the sand mold at the center of the mold cavity. It was found, however, that nickel-silver does not rest quietly on the bare surface of the metal chill, and it was necessary to prepare special chills for this purpose.

A simple solution to this problem would be to design the top or bottom face concave instead of flat. This reduces the sectional thickness in the center sufficiently to prevent premature solidification.

CONTRACTION SHRINKAGE: Up to this point the discussion has been confined to volumetric shrinkage. But after solidification takes place, there is a further reduction in the size of the casting. This is called contraction shrinkage.

As a result of contraction shrinkage, the casting at room temperature is smaller than the pattern or mold cavity formed by the pattern. This reduction in size is corrected by making the pattern larger by an amount equal to the shrinkage of the particular metal used. With the use of shrinkage tables and good judgment, allowance for size usually is not a serious problem.

In large-scale production of castings, dimensional stability and accuracy become more precise requirements, and considerable experimentation and research are necessary to produce refinement in results.

Casting May Break

If the force resisting shrinkage is great enough, the casting may warp or break. Some years ago a customer presented a foundryman with a pattern for an experimental design. It consisted of two cross-arms joined with a connecting link. The customer was warned that a hot tear might occur and was told why this would happen. The customer was not convinced and offered to pay the bill, defective casting or not. The casting was delivered in three pieces.

The skilled foundryman has many routine methods to avoid hot tears but often must resort to ingenious techniques. He knows all too well that the weakest part of a casting is at the hot spot, and if the hot spot lies in the path of stress, a tear is likely to occur.

An effective way to prevent a hot tear is to avoid the hot spot by design. When a casting shrinks under good design conditions, it may have the strength to withstand the stress in spite of mold or core obstruction.

Sometimes a casting may not tear but will fail to shrink because of obstruction. If this occurs on the diameter of a cylinder because of core ob-

struction, for example, the cylinder will have excessive metal on the outside for finishing and will lack metal inside for a bore finish.

STRESS PROBLEMS: The greatest and most frequent stress problems confronting foundrymen are caused by casting design. Whenever there is temperature gradient in a casting, shrinkage difficulties may be encountered. The rate of shrinkage in a casting is directly proportional to the rate of change in temperature. Thus, a thin section will cool rapidly and its dimensions will decrease at a rapid rate. At the same time the heavy sections may be shrinking very little or possibly not at all because their centers are still molten or very hot.

Being at a high temperature, the heavy sections may have sufficient plasticity to adjust themselves to the rapidly changing thin sections, or in other situations the sections may separate. If separation does not occur in this phase then some time later, when the thin sections have passed through the greater portion of their shrinkage cycle and have become relatively rigid, the heavy sections begin to contract.

This time the shrinkage of the heavy sections is being obstructed by the rigid thin sections. The outcome of this action may be a warped casting or a tear in the junction where thick and thin sections intersect.

By designing a casting so that all external sections are of uniform size and the internal sections are reduced to four-fifths the size of the external sections, a sufficiently constant temperature can be maintained throughout to minimize casting defects resulting from contraction shrinkage.

From a paper entitled "Casting Design for Economical Production," presented at the 59th Annual Meeting of the American Society for Engineering Education, East Lansing, Mich., June 25-29, 1951.

Utilization of Engineers

By Carey H. Brown

Chairman, Engineering Manpower Commission Engineers Joint Council New York, N. Y.

BEYOND the necessity for technological preparedness in the military sense the engineering profession is faced with the challenge of increasing the productivity of industry and improving the material standard of living. Maintenance of strength in our civil structure as well as in our military establishment is essential. In both, the role of the engineer is a

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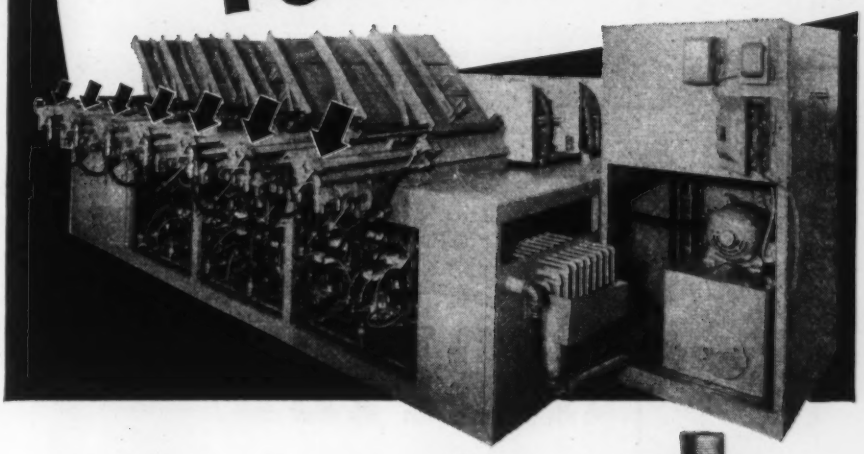

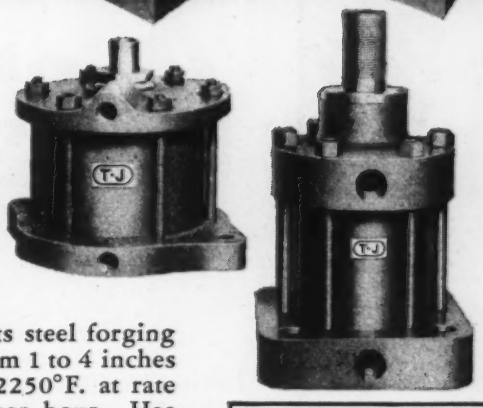

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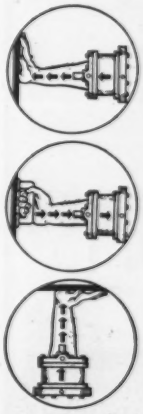

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dominant one; supply of engineering manpower is a critical problem; the failure to make full utilization of available engineering skills is a wasteful procedure which must be eliminated.

For purposes of a review as to what has been done and the suggestion of a program for the profession, proper utilization of available engineers may be considered under three headings:

1. Engineers in private employment
2. Engineers in civil government—national, state, or local
3. Engineers in the armed services.

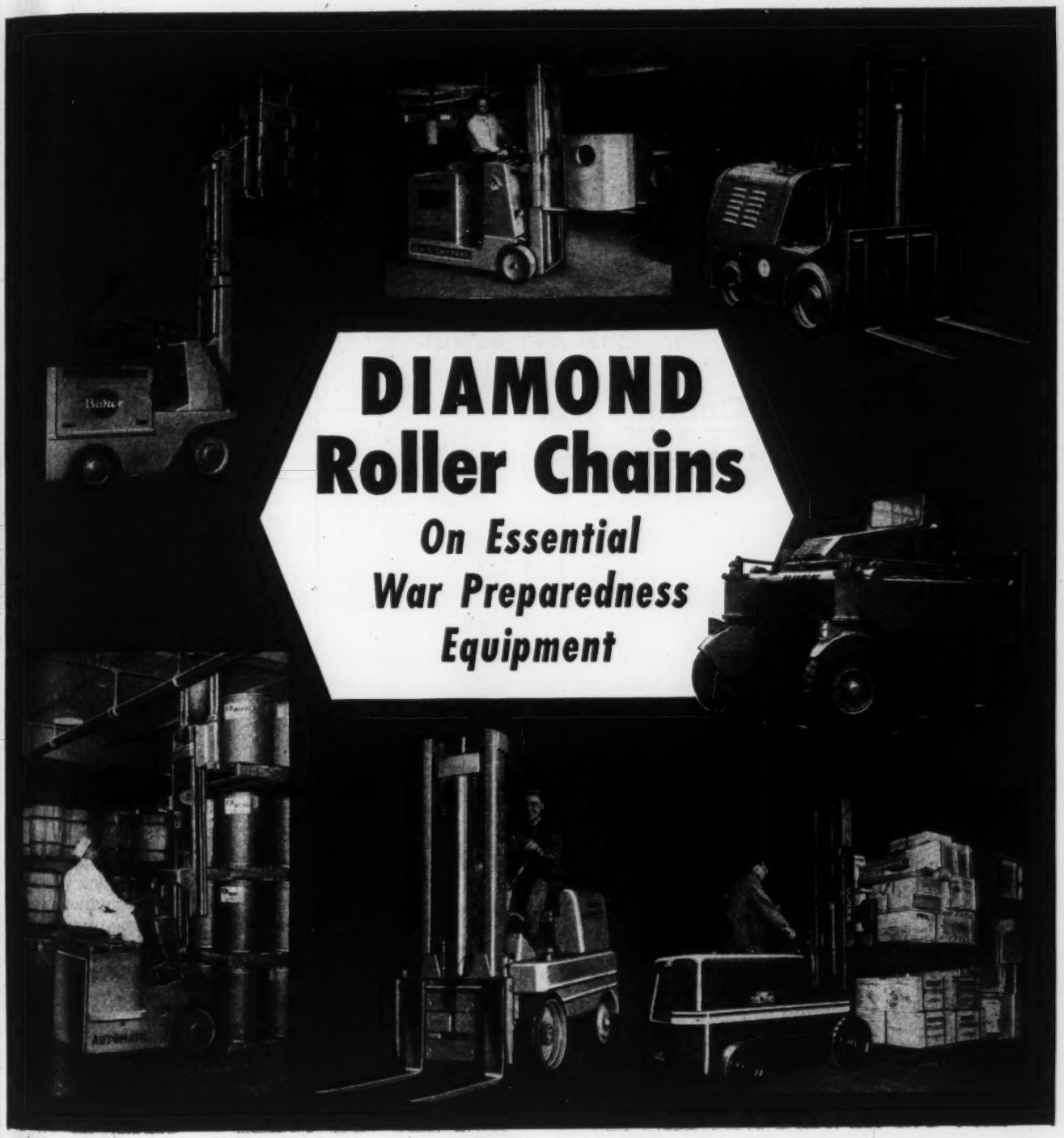
Of engineers in private employment a major portion are engaged in industry. Needs of various industries for engineers vary in accordance with the nature of the industry itself and to some extent—where engineering design or practice is not, strictly speaking, required—with the predilection of the individual employer as to the type of personnel and training which gives him most effective results. The nature of the activities of engineers engaged in sales, purchasing, and the like varies so much from place to place that it is impracticable to make any sound generalization with regard to the justification for the use of engineers in such positions during an emergency such as now faces us.

Two factors enter the situation. The first is that engineers who have been so employed for any considerable length of time probably now lack knowledge of skills and techniques essential in the fields of design, development, and mechanical or chemical production, where our greatest needs exist. The second factor is that engineers who are nonessential in their present positions, whatever they may be, will probably be drained off into more essential engineering activities as demand for their services maks itself felt.

Young Engineers Needed

It is the engineer engaged as such in private industry, along with his counterpart in the Armed Services, who is the critical figure in the present shortage. The young engineer is in many cases equally, sometimes even more, in demand than his more experienced confrere, for much of the technology now critically important is so new that only recent students have any training whatever in its application. A belief that the technical requirements of industry can be met by men generally over military age, even if there were enough of them, is therefore a fallacy.

As a means of assuring prompt integration into industry of newly employed engineers, with consequently more effective advancement and utilization of their skills, the Engineering



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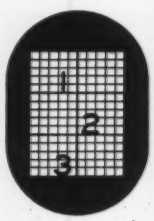

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Manpower Commission has urged upon industry the establishment of high-level training courses comparable to hospital internships of the medical profession. Certainly, within industry itself, every effort must be made through training, reassignment, up-grading and the like to meet present requirements. Steps of this nature can be made effective only by local action in individual industries. The pressure of scarcity probably will automatically lead to such measures in time, but preferably they should be initiated early to avoid loss of production which otherwise will occur. Many projects or plants are now suffering from a lack of engineering know-how which is available somewhere else. In a free economy groups of private citizens cannot be reshuffled at will; but employers of engineers must at least avoid the taint of hoarding unneeded technical employees in these times when a critical shortage in overall supply is evident.

Government Program Developed

With regard to engineers employed as civilians in governmental agencies, national, state and local, certain steps have been taken upon initiation by the U. S. Department of Labor. The U. S. Civil Service Commission issued instructions to all Federal agencies regarding the development of a program for maximum utilization of engineering personnel within the Federal Government and a program is underway to explore the possibilities of utilization of engineering personnel of state, county and municipal governments on a full-time or part-time loan basis to Federal defense agencies and to other vital defense activities.

The U. S. Office of Education has developed plans for a reactivation of the Engineering, Science, Management War Training (ESMWT) program followed during World War II for intensive, short-term courses in colleges and universities. This National Defense Training Program is designed to prepare persons for specific employment in defense-production establishments. All of the engineering schools and colleges have been requested by the Office of Education to cooperate in making available the services and facilities of these institutions, including part-time employment of engineering students and faculty members, to assist key defense industries urgently in need of such assistance.

The problem of the engineer and the Armed Services is an extremely difficult one. The proposed legislation which later led to enactment of the 1951 Selective Service Act at one time contained a provision for

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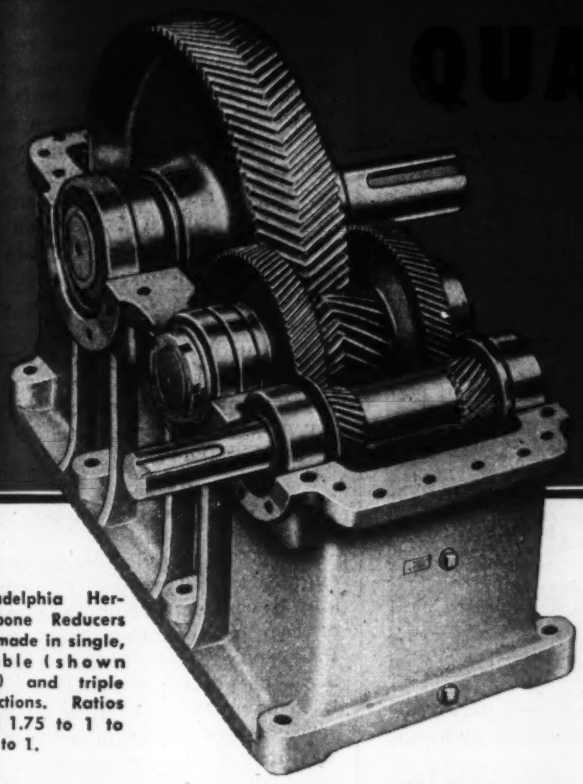

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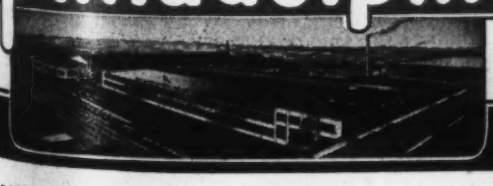

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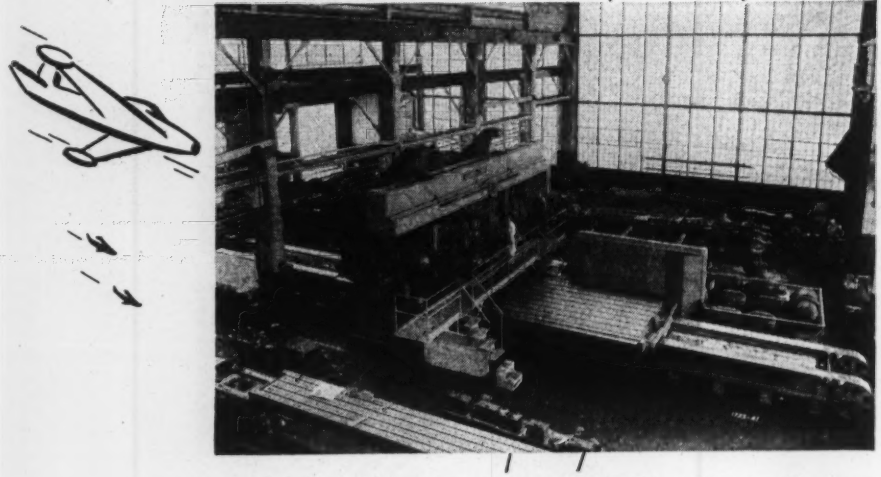

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the exemption each year of 75,000 young men to enter technical and scientific training. This would include engineers, doctors, physicists, chemists, etc.

While this provision was pending, the President issued a Selective Service memorandum providing for the deferment of an indefinite number of college students conditioned upon class standing and record in a special examination to be given to applicants for such deferment. This created such a furore that Congress eliminated the proposed provision, and the selective service memo was modified to provide that results of the deferment examinations should be considered by local draft boards as one factor in reaching a decision. Furthermore Congress, apparently because of the public outcry against exemption or indefinite deferment of any group, added a provision to the effect that deferment for *any* cause makes an individual subject to the draft until he reaches the age of thirty-seven.

The justice of adding perhaps ten or fifteen years to the period of draft liability of a student deferred, say, for one year to complete his course is questionable.

Deferments Set Up

The effect of Selective Service upon engineers or prospective engineers may be considered from the standpoint of two groups other than students. Provisions for consideration of deferment of engineers in defence industries have been set up in the various services, but variation between services and arbitrary action in many cases have caused considerable difficulty. No sound procedure has yet been evolved for proper determination of the value to the *materiel* aspect of the Armed Forces of an engineer in defense industry as compared to the value of the same man in uniform, where he might or might not be utilizing his engineer training.

The latter possibility, that he might not be utilizing his engineering training, has seemed all too prevalent. The Commission has received notice of so many cases of this nature that there is evidence of a deplorable lack of policy for assuring that engineering and scientific skills among draftees are recognized as a basis for routing to assignments.

The reservist problem has some of the same aspects—and some of its own. The Armed Services must be given credit for preserving records of the qualifications of their reservists, but the difficulty lies in the fact that in calling a reservist the services think of the qualifications of the individual as of six or more years

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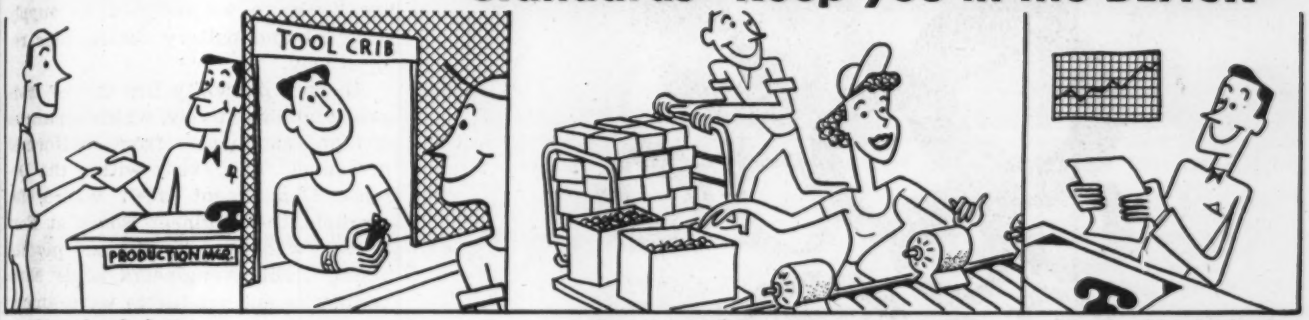

Standard design and purchase | Standard tools | Standard (fast) production with "standards" from stock | Standard (or higher) profits

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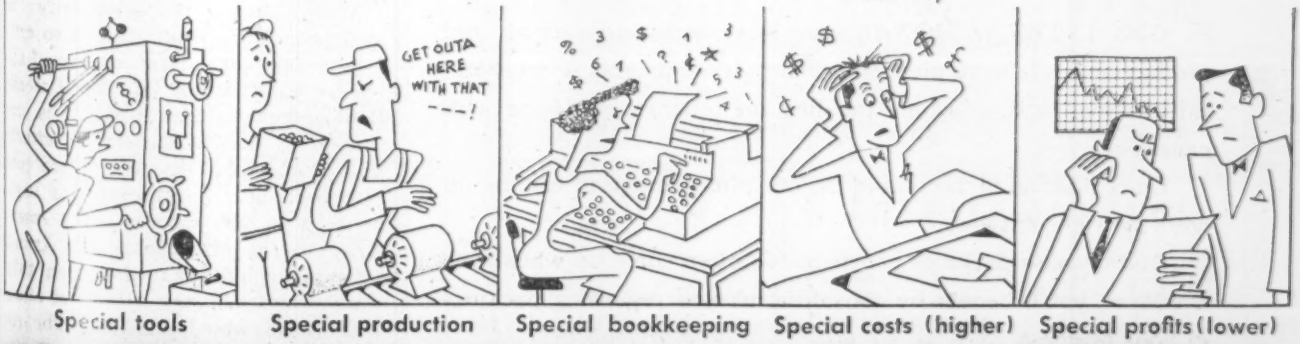

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ago. During that period many a young man, through the G.I. Bill or otherwise, has acquired a technical education and possibly practical experience as well. The young man who was a supply sergeant in 1945 may now be an electrical engineer with a couple of years experience in electronic controls. The fellow who got his B.S. in the early forties and was a battery commander at the end of the war may now be a process engineer in a chemical plant. But those two men, if called back into service, are likely to be assigned as supply sergeant and battery commander respectively.

Another difficulty lies in the wide gap, administratively, which separates civilian employees from uniformed personnel. This exists within the Defense Department itself where, for example, the Engineer Board at Fort Belvoir was combing the colleges for young civilian engineers while some twenty recent graduates were among a group of draftees who had just arrived. The detail of draftees to other agencies, such as the Atomic Energy Commission, is surrounded with still greater difficulties.

Administrative Action Necessary

Action in some individual cases, in recent times and during World War II, has been encouraging, but these cases are all too few. Proper overall handling of the situation requires the development of an entirely new administrative routine with regard to individuals of special qualifications. The old policy of assignment according to availability must be improved.

Maintenance of superiority in weapons and in production is so critical to this nation that continued apparent indifference of the Defense Department to this situation is unthinkable. One of the several efforts to find means of securing more consideration of the utilization of engineers was met with a reply essentially to the effect that the Armed Services would take what men they wanted and industry would get along with those who were left. The recent appointment, under the Chairmanship of Dr. Flemming, of a Committee on Specialized Personnel promises a means of bringing more forcibly to the attention of the Defense Department the necessity of securing technically trained men to technical jobs where their training is fully utilized. Otherwise our superiority in weapons will be lost.

From a paper entitled "A program for the Engineering Profession," presented at the National Engineering Manpower Convocation in Pittsburgh, Pa., September 28, 1951.

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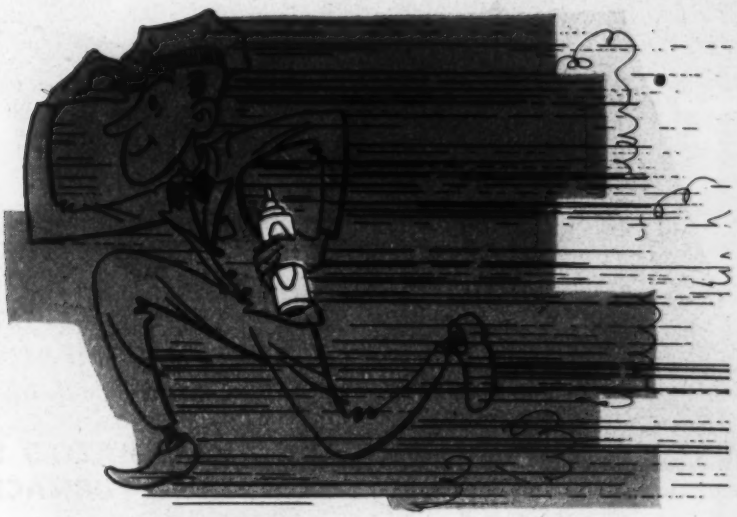

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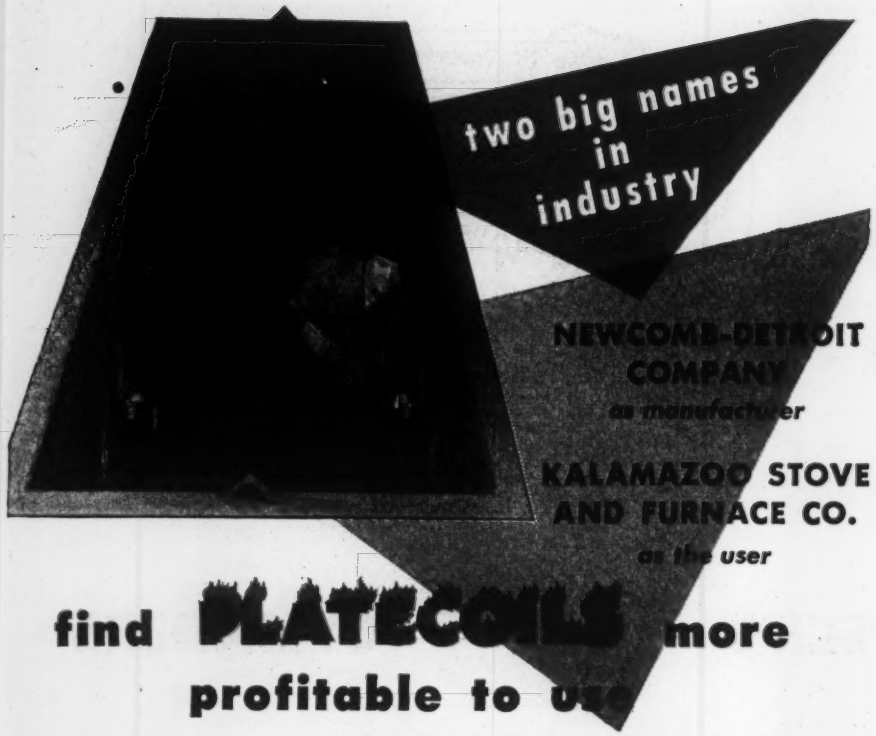
MACHINE COMPANY, INC.

1210 150th Street, Hammond, Indiana



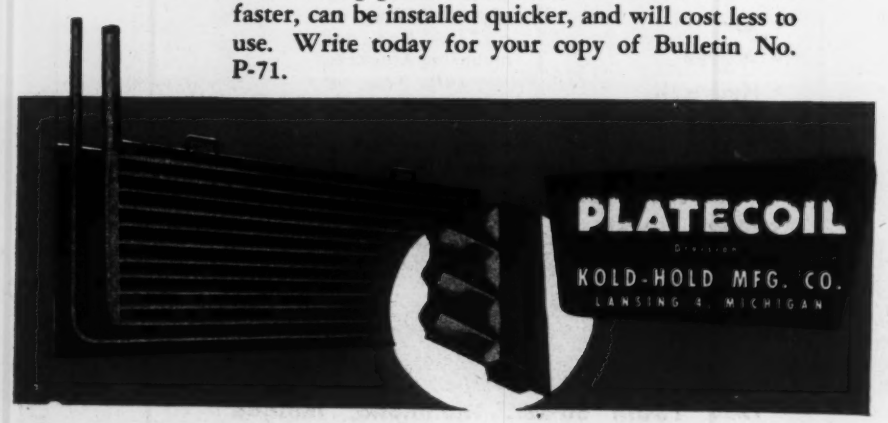
find PLATECOILS more profitable to use

It is less costly to buy and install Platecoils than it is to fabricate pipe coils in their own plant according to Robert Dill, Plant Superintendent of the Newcomb-Detroit Company, Grand Rapids Division. In building the hot rinse tank pictured above they have realized many advantages resulting from the use of Platecoils both for themselves and their customer, Kalamazoo Stove and Furnace Co.

Starting with the original estimate, sales engineers find it much easier to determine the coil size from the convenient Platecoil chart. And Platecoils can be depended upon to deliver the amount of heat specified in their B.T.U. rating. In the construction of the tank, Platecoils are easier to handle and fabrication time and labor are reduced. A Platecoil with the equivalent B.T.U. capacity as pipecoil takes only half the space in the tank thus leaving greater working area. This is important also to Kalamazoo Stove and Furnace Co. as the user.

The extra tank capacity comes in handy in the use of the tank as part of an acid etching system used for pickling aluminum prior to spot welding on aircraft parts. And the higher B.T.U. capacity of the Platecoils provides faster heating and quicker starts.

Wherever pipecoils are used, Platecoils will heat faster, can be installed quicker, and will cost less to use. Write today for your copy of Bulletin No. P-71.



News
OF MANUFACTURERS

DEVOTED exclusively to molding silicone rubber parts, a new plant has been opened in Minneapolis by the **Minnesota Silicone Rubber Co.**, an affiliate of **Minnesota Rubber & Gasket Co.**, also of Minneapolis. A special injection molding process developed by company engineers makes possible the economical molding of silicone parts to extremely close tolerances with a low rejection rate.

♦

In order to increase the overall efficiency of its service network, **Mack Trucks Inc.** has begun construction of a modern service parts plant. Located on Route 29 in Bridgewater, N. J., the parts building and offices will occupy approximately 425,000 sq ft. It is expected to be in operation by the first of next year.

♦

Stronghold Screw Products Inc., Chicago, has announced that its western affiliate, **Stronghold Pacific Corp.**, has acquired the stock ownership of Rivco Inc., Downey, Calif., manufacturer of commercial, aircraft and automotive fasteners.

♦

After six years of idleness following World War II, the **Diamond Magnesium Co.** plant in Painesville, O., is again producing magnesium ingots. Eforts are being made to have the plant at full production by the end of 1951.

♦

Manufacturing facilities of Highway Steel Products Co., Chicago Heights, Ill., have been acquired by **United States Radiator Corp.** Facilities are set up for processing both steel and aluminum and include welding equipment, heavy presses for stamping and forming and a finishing department for bonderizing and enameling. The plant will be devoted fully to war contracts and other defense needs.

♦

A "Productive Maintenance" plan, designed primarily to assist maintenance engineers in setting up a program to minimize lost production time and forced idleness due to equipment failures, has been announced by the **General Electric Co.** The plan will also provide better spare parts control, smoother production flow, and enable industry to gain optimum out-

MADE TO TAKE THE WORST...
GIVE THE BEST IN PRODUCTION
Throughout the nation on the most grueling drives Atlas Roller Chain has been torture-tested. Proved its ability to take the worst in severe service and deliver the best.
Atlas Roller Chain is made to provide more production. It assures positive sprocket grip which makes possible the delivery of full rated horsepower without slippage or friction. Your machines can run at full rated speeds and give greater output.
Atlas Roller Chain is built for less maintenance. Bushings and pins are case hardened by the Atlas Nicarb Process which provides greater inherent strength. Link plates and rollers are made of tough, heat-treated alloy steel. Result . . . better chain performance . . . less chain maintenance.
For maximum production, plus long, trouble-free service, install Atlas Roller Chain. Available through leading industrial distributors from coast to coast. Write today for new Atlas handbook and catalog on roller chain.
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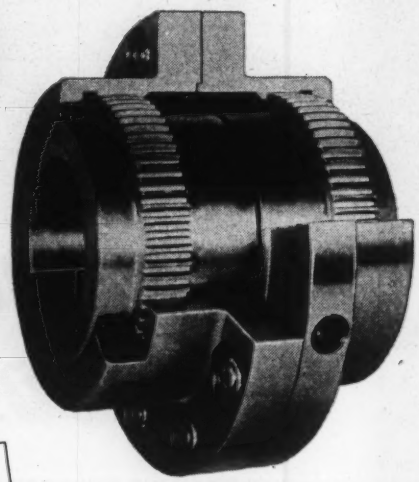
ATLAS ROLLER CHAIN

an advanced design accounts for the savings they insure

WALDRON *Improved* GEAR TYPE Couplings



LARGER BORE

New WALDRON design affords a larger maximum bore to permit use of larger shafting, smaller physical capacity for same size shaft with reduced rotating weight.

STRONGER CONSTRUCTION

WALDRON cover sleeve is one solid forged steel unit. With *no welded parts* the accurate gear in sleeve cannot become distorted. Added assurance of safety at high speeds.

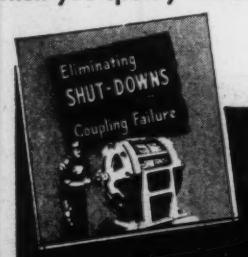
EXTRA PROTECTION

WALDRON oil and dust seal, impervious to mineral lubricants, hermetically seals against oil oxidation. Ever present oil film carries load with no possibility of wear from metal-to-metal contact.

MOST ECONOMICAL

Their past performance records coupled with new design and construction features combine to prove WALDRON Couplings the most economical to buy as well as use for longer service life.

The same engineering skill that developed the improvements on gear coupling design is always available for special application couplings and any other service when you specify WALDRON Couplings. Write for this helpful folder explaining coupling features which give added insurance against coupling failure. No obligation.



JOHN WALDRON
CORPORATION
New Brunswick, New Jersey
Authorized Sales Representatives in Principal Cities

put from existing equipment. A file-size kit of maintenance aids designed to guide the engineer in setting up a working program and a supplementary slidefilm are available from the company.

♦

B. F. Goodridch Chemical Co., a division of **The B. F. Goodrich Co.**, will construct a new plant in Calvert City, Ky., 27 miles southeast of Paducah. The project is expected to be in operation late in 1952 or early 1953. First material to be produced will be vinyl chloride monomer.

♦

To adequately serve a growing number of users of precision investment castings, the **Hitchiner Mfg. Co. Inc.** has moved from its plant in Manchester, N. H., to a new and larger factory in Milford, N. H.

♦

A $500,000 modernization of its Oil City, Pa., plant is planned by **Worthington Pump and Machinery Corp.** Plans include re-equipping the present foundry and establishing a new electric power supply. New molding machines, sand conditioning and sand supply equipment, as well as new mold drying ovens, will be installed.

♦

To avoid confusion with similarly named manufacturers, the Lyon-Raymond Corp. will henceforth be known as **The Raymond Corp.**

♦

A new factory opposite the range plant of **Hotpoint Inc.**, Chicago, has been opened for production of jet engine components, with pilot runs scheduled for this fall. It will operate with the range factory as a twin plant facility for civilian and defense output.

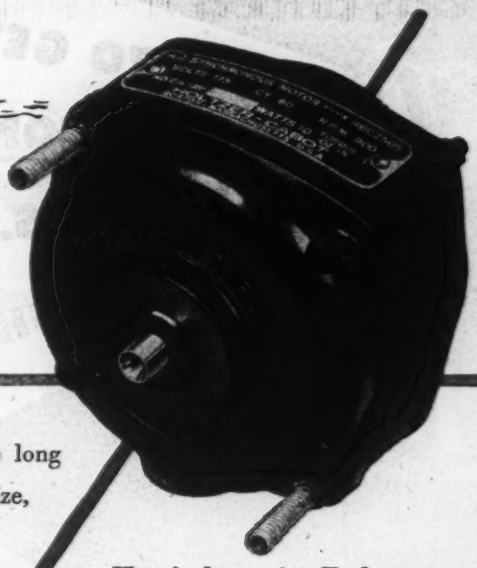
♦

Turco Products Inc., Terminal Annex 2649, Los Angeles 54, Calif., has been selected as the new Dy-Chek division of **Northrop Aircraft Inc.**, and has assumed both manufacturing and distributing functions.

♦

Hyatt Bearings division of **General Motors Corp.** has announced that preliminary plans are now complete for expansion of the manufacturing areas in the Hyatt plants in both Harrison and Clark Township, N. J. New structures at the Clark Township plant will provide an additional 390,000 sq ft of floor space, doubling the existing facilities, and alterations to the Harrison plant will provide an additional 12,000 sq ft of manufacturing

Now – greater safety for small boats!



This Holtzer-Cabot motor helps the Fathometer* make 900 soundings per minute!

Owners of small pleasure boats and fishing craft have long wanted a reliable depth sounder that would be small in size, economical in power consumption and low in price.

Now, the Submarine Signal Division of the Raytheon Manufacturing Co., Waltham, Mass., is filling that need with the Fathometer, an echo depth sounder that is amazingly accurate and compact.

The Fathometer CADET shows depths from 1 foot to 160 feet, and indicates the slightest changes in bottom contour. It has proven to be an invaluable aid not only in guiding boats safely through unfamiliar waters but also in discovering and indicating the location and depth of schools of fish.

Here's how the Fathometer works: A transducer installed inside the hull sends out sound waves and picks up the echoes that are "bounced off" the bottom. Depths are indicated by the flash of a whirling light registering against a calibrated dial. The accuracy of these readings is controlled by a Holtzer-Cabot synchronous motor which receives its driving power in the form of "square wave" AC from the vibrator power supply.

Rigid specifications were laid down for the motor to serve in the Fathometer.

The motor specified had to be a slow speed (900 RPM), synchronous type, 115 volts, 60 cycle single phase with 0.1 ounce inches torque. It also had to be totally enclosed and suitable for continuous duty, with input of 11 watts under full load.

Other specifications: – ability to operate in an ambient temperature range of 0° to 50° C. without exceeding a maximum temperature of 105° C.; minimum life, 1000 hours of operation.

Holtzer-Cabot met this set of requirements by developing a special version of the Holtzer-Cabot RBC – 2505 motor, which is now giving excellent service.

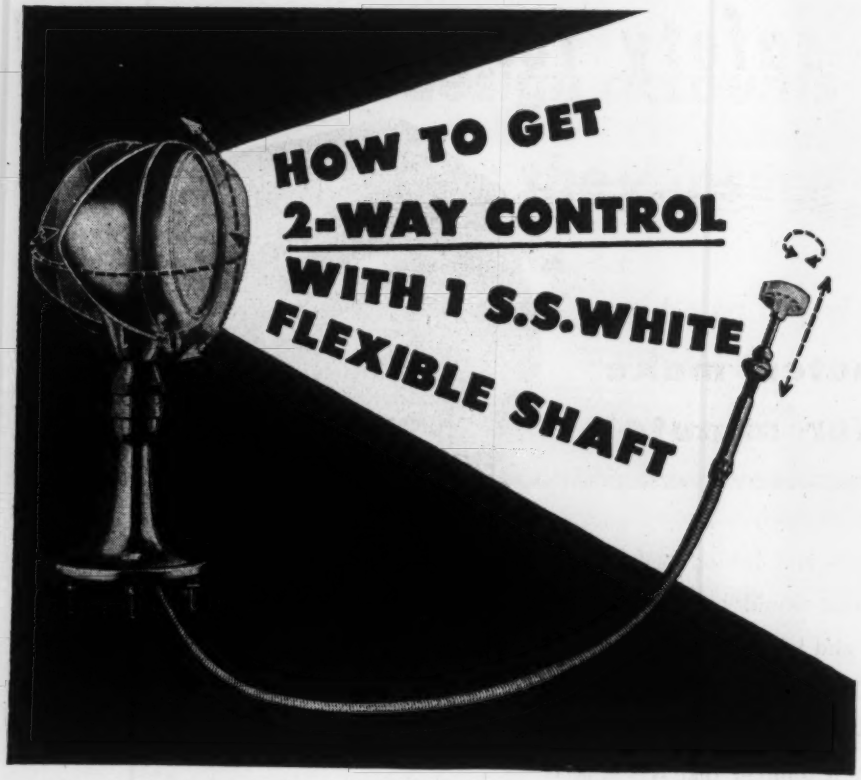
This is just another example of Holtzer-Cabot's ability to meet the most demanding specifications in small-motor applications. Holtzer-Cabot motors range from 1/2000 up through 1½ H.P.; from 12,000 RPM to 1 revolution per day!

HOLTZER-CABOT

DIVISION OF NATIONAL PNEUMATIC CO., INC.

BOSTON 19, MASSACHUSETTS

"Manufacturers of fine electrical apparatus since 1875"



Courtesy Arnolt Co., Warsaw, Ind.

HERE'S an "on-the-spot" answer to the problem of providing equipment with a combination of push-pull and rotary control. As the illustration shows, with only a single S.S.White flexible shaft, the light can be swung the full 360° arc and tilted up or down simply by turning the control knob or by pushing it in or pulling it out.

In addition to the obvious advantages of such an arrangement, the S.S.White flexible shaft is easily installed and allows both the light and its control knob to be mounted in the most desirable location.

If you'd like to get further details on the versatility and usefulness of S.S.White flexible shafts.

♦

WRITE FOR NEW BULLETIN 5008

It contains the latest information and data on flexible shafts and their application. Write for a copy today.

S.S.White MAKES IT RIGHT

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.

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Western District Office • Times Building, Long Beach, California

area. The new areas will be used exclusively for producing bearings for the defense program.

♦

Emphasizing the importance of properly applied electrical equipment for increased production, a travelling industrial power exhibit is being sponsored by **Westinghouse Electric Corp.** and its distributors. The exhibit, called "More Production Ahead," is on tour of industrial centers as part of a planned power distribution program.

♦

Castalloy Co. Inc., Everett, Mass., has reactivated its magnesium and heat-treated aluminum foundry facilities. The company is already producing the aircraft and Ordnance castings in which it specialized during and after World War II.

♦

Construction of a $2,500,000 plant has been announced by **Fairfield Manufacturing Co.,** Lafayette, Ind., maker of gears and differentials. It is expected that the building will be ready for occupancy before the end of this year. It will provide the company with 181,000 sq ft of floor space to house office, engineering, and manufacturing departments.

♦

Buick Motor division of **General Motors Corp.,** Flint, Mich., has made available for defense work 1,200,000 sq ft of floor space previously devoted to automobile production. The company has a prime contract with the Government to produce CD-850 tank transmissions and Wright J-65 Sapphire jet engines.

♦

Construction is under way at the Jamaica bauxite deposits of **Kaiser Alum'num & Chemical Corp.** to supplement present aluminum ore sources by 1,000,000 tons a year.

♦

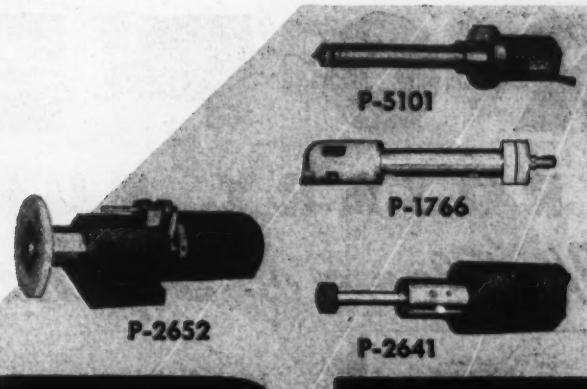
United Manufacturing Co. has annouced that completed expansion into a second plant will double the present manufacturing facilities of Caravan axles, retractable landing gear and brake controls for industrial, farm and military applications. The new plant is located adjacent to the company's original plant in Bedford, O.

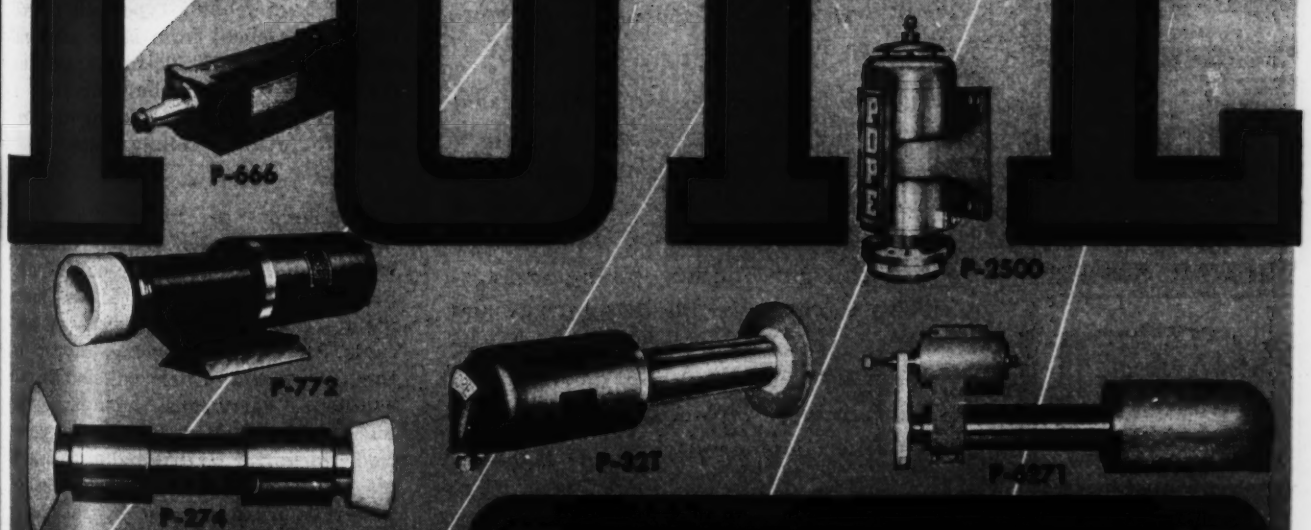
♦

J. M. Martin and C. L. Ramsey, both of the School of Chemical Engineering, Georgia Institute of Technology, Atlanta, Ga., were awarded first prize in the prize competition for papers on "Technological and Research Aspects, Advances and Advan-

For
PRECISION SPINDLES...
Specify

POPE





Whatever the type or size of Spindle you need, let POPE be your spindle department.
It pays off in terms of finer finishes and continuous production of accurate parts.

The POPE System of sealed-in lubrication assures permanent bearing lubrication and long life.

Let us have your specifications so we can send you price and delivery estimates on the one best spindle for your job.

No. 79

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BUILDERS OF PRECISION SPINDLES

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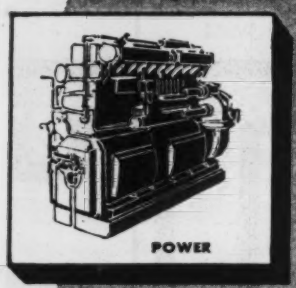
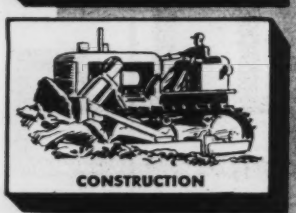
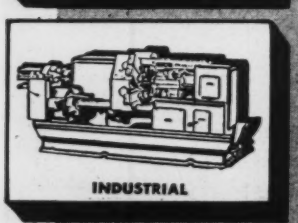
ROTARY PUMPS

The Name of Dependability







Widely Used in Diversified Industries

Whether your equipment is dependent upon a pump for fuel transfer, coolant work, or hydraulic action, you will maintain greater operating efficiency with the rugged Roper — Series F. This series is built to pump clean liquids of all kinds, and is available in standard or special-built designs in 1 to 300 g.p.m. . . . pressures to 300 p.s.i.

Standard-fitted pumps are self-lubricated by the liquid being pumped . . . helical gears of equal size run smoothly in axial hydraulic balance . . . precision ground and hardened drive shaft . . . 4-port design permits eight optional piping arrangements to cut down installation time and costs. Investigate dependable Roper pumps now and learn how they can help you in new or replacement installations. Send the coupon today!

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ROPER *Rotary Pumps*

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tages of the Use of Lower Melting (lower than parent) Filler Metals in the Non-Fusion Welding Process," conducted by **Eutectic Welding Alloys Corp.**, Flushing, N. Y.

♦

The A. W. Haydon Co. of Waterbury, Conn., was purchased recently by **The North American Philips Co. Inc.** and will be operated as a division of the latter company. The Haydon company is now devoted almost 100 per cent to filling Government contracts for timing motors, electric controls for aircraft and electronic devices.

♦

A new plant of 20,000 sq ft, which will double production space for the manufacture of plastic products for the chemical industry, is being built by **American Agile Corp.** in Maple Heights, O.

♦

Brooks & Perkins Inc., Detroit, has begun construction of a new magnesium rolling mill in suburban Detroit. It will be a jobbing-type mill to roll magnesium sheet from slabs and will be provided with 25-ton travelling cranes in the mill building and a complete melting and casting department for making rolling slabs.

♦

Completion of Plant No. 4 of **American Phenolic Corp.**, Chicago, will permit an expansion in AN and RF connector assemblies at the main plant. Plastic molding presses and cable extruders are being moved to the new plant, which will house all synthetic operations including the molding of plastics, wire mill operations including extruding and braiding, and will warehouse supplies of materials used in these operations.

♦

The Precision Tube Co., Philadelphia, has announced plans for a new manufacturing plant and office building to be located at North Wales, Pa. The plant will produce nonferrous seamless tubing of sizes from 0.500 to 0.010-in. OD. A control and engineering laboratory to assist customers in solving their tubing problems will be included in the new building.

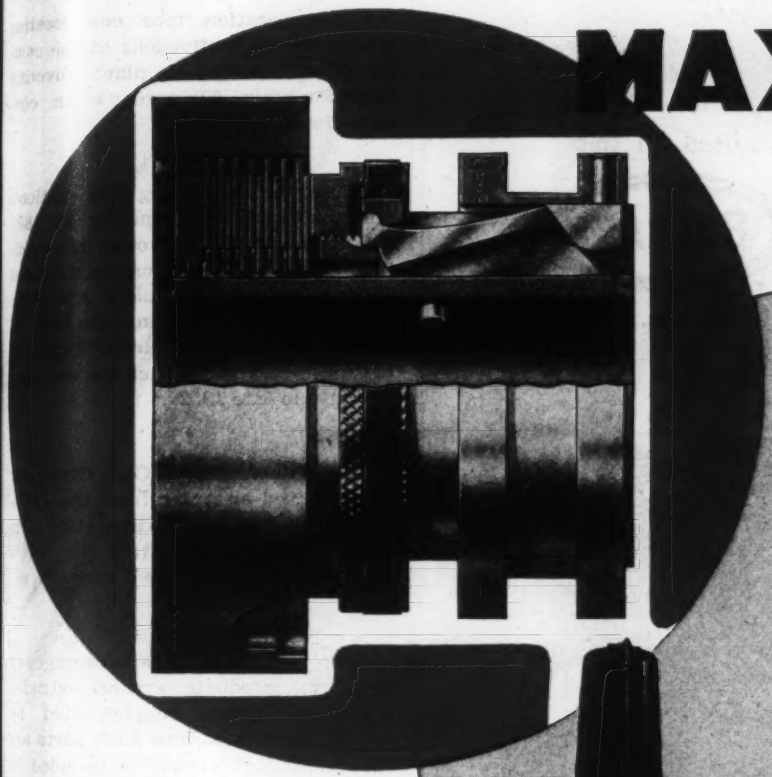
♦

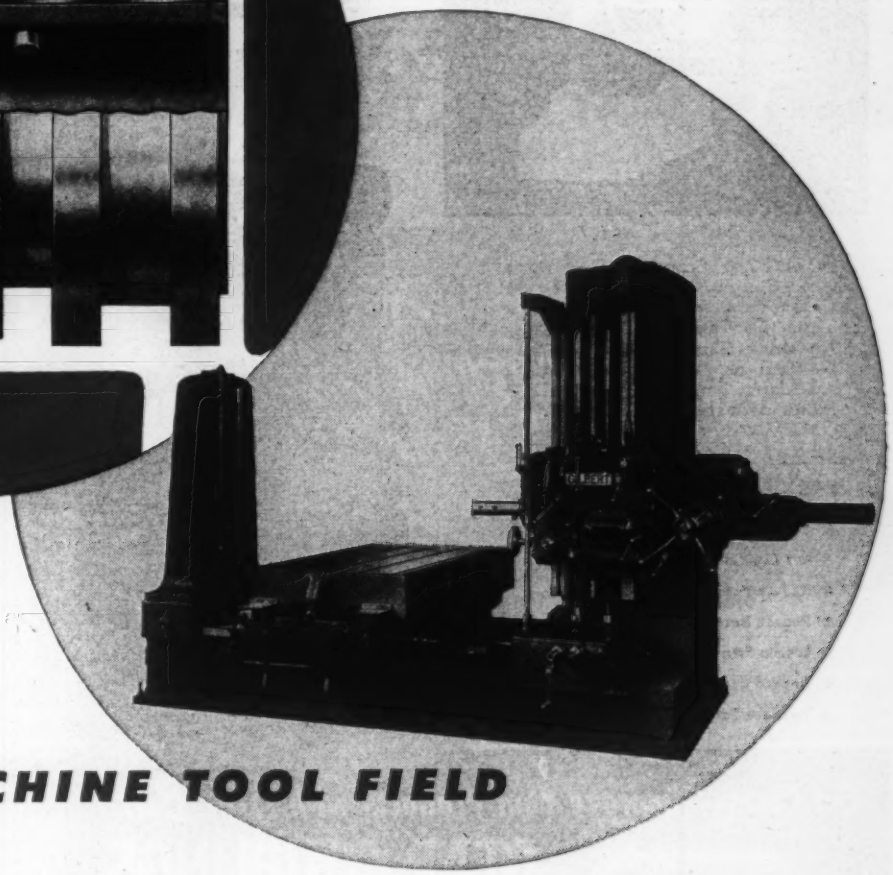
A new plant has been opened in Ferndale, Mich., by **Morton Machine Works.**

♦

The Structural Steel division and the Steel Deck Division of **The R. C. Mahon Co.**, have now been moved to the company's new plant on East Eight Mile Rd. at Sherwood Ave., Detroit. This move brings the entire

MAXITORQ
KEEPS GOOD COMPANY





...IN THE MACHINE TOOL FIELD

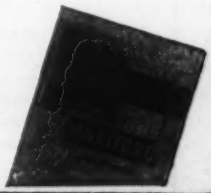
It is a pleasure to express our appreciation to the Cincinnati Gilbert Machine Tool Co. for their selection of our No. 25 Maxitorq Clutch as original equipment in their Gilbert Horizontal Boring, Drilling and Milling machines.

The multiple "floating disc" single Maxitorq Clutch (3 h.p. at 100 r.p.m.) is located on the initial shaft in the Unit Head, controlling the r.p.m. of the spindle.

Maxitorq Clutches are available in 8 standard sizes, fractional to 15 h.p.... single or double, wet or dry. "Floating discs" ride free in neutral, preventing drag, abrasion, heating. Clutch is completely assembled on the body, shipped ready to slip onto a shaft. All assembly, adjustments and take-down are manual. Varied Maxitorq Driving Cups may be ordered for specific needs.

Within its capacity there's no more compact or dependable clutch than Maxitorq. Check with our Engineers for solution of your problems in power transmission.

Send for Bulletin MD10, "Maxitorq Goes to Work"... showing 16 interesting installations by leading industrial users.



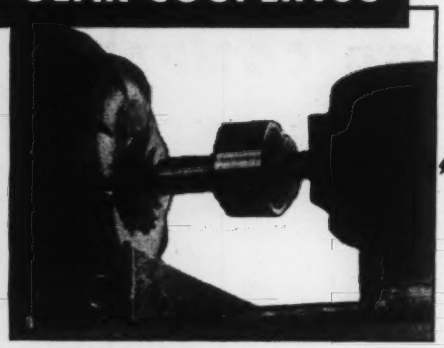
THE CARLYLE JOHNSON MACHINE COMPANY
MANCHESTER • CONNECTICUT

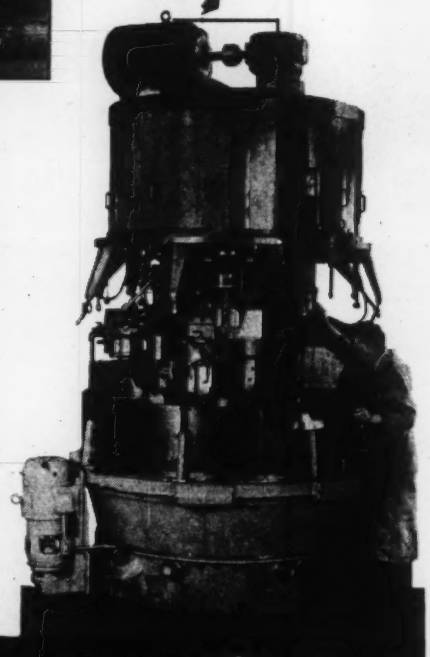
4CJ51

New Sier-Bath FLEXIBLE GEAR COUPLINGS

..... Used On This

BULLARD MULT-AU-MATIC



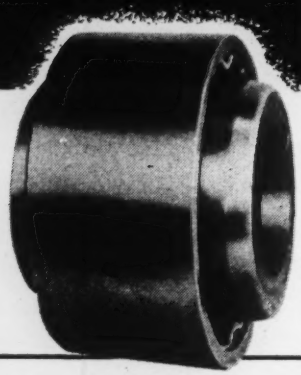


SIZE 2½ Standard Sier-Bath Gear Coupling connecting the 50 HP motor with the main drive of a Type "D" 6-Spindle Bullard Mult-Au-Matic. This coupling may also be used on the 8-Spindle Mulf-Au-Matic, connecting the 60 HP motor with the main drive.

SIER-BATH GEAR COUPLINGS PROVIDE THESE ADVANTAGES:

- Cut Coupling Weight 50%
- Cut Coupling Size 40%
- Reduce Coupling Assembly Time
- Reduce Uncoupling Time
- Lessen Strain on Shafts, Bearings
- Reduce Coupling Parts Problems
- Increase Safety

Cut Costs---Improve Your Products with Sier-Bath GEAR COUPLINGS

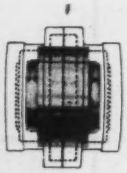


MORE and more well-known manufacturers are modernizing their direct drives with the revolutionary Sier-Bath Gear Couplings. Light, compact, stream-lined—these new couplings eliminate bolts, nuts, grids, discs—reduce the gear coupling principle to its simplest, most efficient form. They provide plenty of flexibility, transmit the whole load from hub to hub by means of a powerful, one-piece smooth sleeve. No bolts to shear, seize or corrode . . . faster alignment checks . . . less maintenance . . . longer life.

ASSEMBLED, UNCOUPLED in seconds!

ONLY 7 PARTS

3/5 USUAL SIZE
1/2 USUAL WEIGHT



Sier-Bath Gear Coupling compared with two major conventional types of same shaft size, HP rating.

WRITE FOR BULLETIN—gives installation photos, cost-cutting advantages, plan drawings, specs for standard, vertical, mill motor and floating shaft types—sizes from ⅞ to 6, HP 4 to 550. (Special sizes and types on request.)

Founded 1905 Member A.G.M.A.

Sier-Bath GEAR and PUMP CO., Inc.

9263 HUDSON BLVD., NORTH BERGEN, N. J.

Also Manufacturers of Precision Gears and Screw and Gearex Rotary Pumps.

Mahon operation into one location where the eight divisions of the company will occupy a plant covering approximately 57 acres when construction is completed.

♦

Plans for increasing the nation's alumina producing capacity by 180,000 tons annually, through the addition of new production facilities at an existing plant in Mobile, Ala., have been announced by **Aluminum Ore Co.**, a subsidiary of **Aluminum Company of America.** Production is expected to begin in late 1952.

♦

The Weatherhead Co., Cleveland, has received an order from the **Packard Motor Car Co.** in connection with production by Packard of the "Dash 23" version of the J-47 turbojet engine.

♦

A presentation of the advantages of designing products around extruded aluminum parts, supplemented by actual pictures of how such parts are fabricated for service, is included in the new movie "The Shape of Things To Come," recently released by **Reynolds Metals Co.**

♦

The formation of **Waters Manufacturing Inc.** at Waltham, Mass., has been announced. The firm has negotiated a license agreement with **Technology Instrument Corp.**, Acton, Mass., under which it is manufacturing miniature, precision, wirewound potentiometers to the specifications of TIC type RV 7/8.

♦

Electronic Devices Inc. has purchased, for purposes of expansion, Precision Rectifier Corp., which will be operated as the Precision Rectifier division of the parent company. The division is already producing selenium rectifiers for all civilian and military applications at the company's main plant in Brooklyn, N. Y.

♦

Sierra Electric and Manufacturing Co., Los Angeles, has announced the purchase of McDonald Manufacturing Co., plastics and electrical manufacturer. Sierra soon will begin an expansion program planned to increase its facilities for custom molding.

♦

The guided missile division of **Consolidated Vultee Aircraft Corp.** is expanding its Pomona, Calif., annex facilities to provide temporary additional space for engineering laboratory activities. A $50,000,000 guided missile plant to be operated by Convair

Look alike?

YES... but one is of superior quality and costs less than 1/2 as much because of *Accurate* springmaking know-how!

Given a few machines and some wire, anyone can make springs . . . the difference comes in "know-how." And that's what we have to sell at Accurate.

A good example of how Accurate know-how can pay off is the history of the two springs illustrated above. One was made in two operations and required 100% inspection with rejects running as high as 50%. Accurate know-how developed the means of producing this spring *complete in one operation with such unvarying accuracy that inspection could be eliminated.* First cost is lower . . . overall cost is lower.

If you require precision springs in quantity, we would welcome the opportunity to go over your needs with you and make recommendations. Write today.

ASK FOR your complimentary copy of the Accurate Handbook of Technical Data on Springs. It's full of short cuts for making spring calculations.

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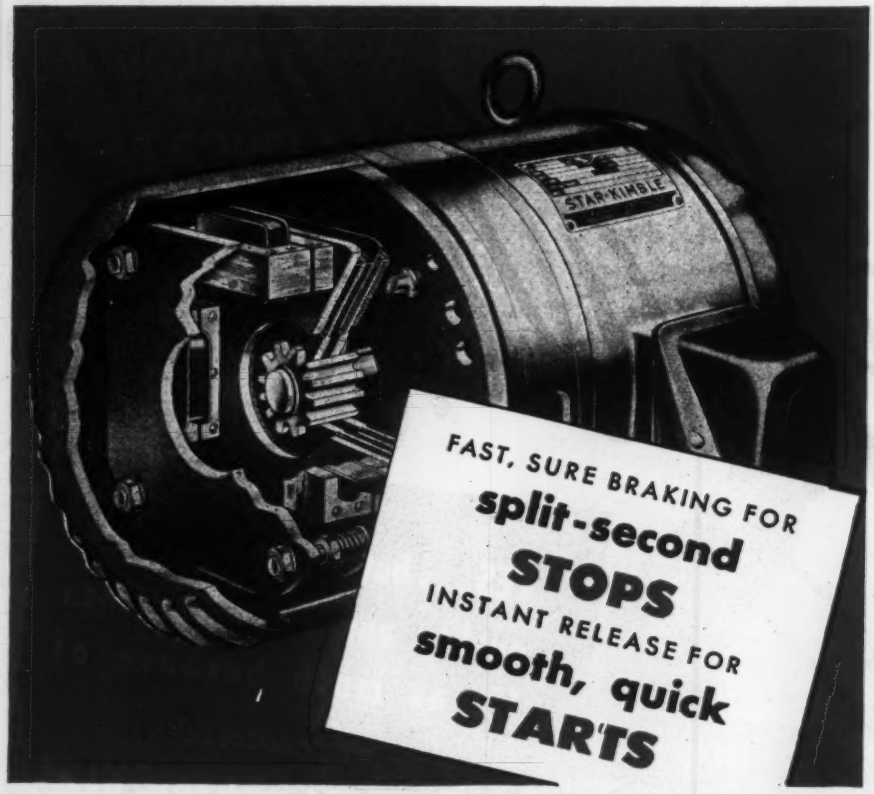
Accurate Springs



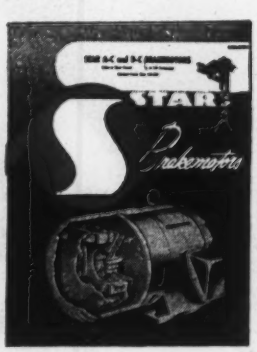
with STAR-KIMBLE BRAKEMOTORS

Where start-and-stop cycles are toughest, you'll find Star Brakemotors on the job, hour after hour, day after day!

The extra-large braking area of Star-Kimble Brakemotors assures quick *stopping*, positive *holding* of the load—gives long service life with little maintenance. Small air gap between electromagnets and brake disc results in extremely fast *release*—allows motor to start smoothly, without friction drag. *Other features:*

Brake discs mounted close to motor for low wear and strain on shaft and bearings. Magnets mounted away from motor for cool operation. Quick, simple adjustment of braking torque. Automatic re-set hand release—an exclusive, patented Star-Kimble feature.

Remember . . . a Star-Kimble Brakemotor is a compact, integral unit—motor and brake *built* together to *work* together. Each Star-Kimble Brakemotor is designed for specific service requirements—by the company that pioneered disc brakemotors and has applied them successfully, for more than 25 years.



Want to know how Star-Kimble Brakemotors work—what torque and motor ratings are available? Write for free Bulletin B-501-A.

STAR-KIMBLE

MOTOR DIVISION OF
[illegible]EHLE PRINTING PRESS & MANUFACTURING CO.

201 Bloomfield Avenue Bloomfield, New Jersey

for the Navy Bureau of Ordnance is being constructed on a 140-acre site in west Pomona. Until this mass production facility is completed next year, the division will operate at San Diego.

♦

As a reminder to operating personnel of their responsibility for the safety of those who use aircraft, **Vol-Shan Manufacturing Co. Inc.** prominently displays a plaque bearing the following inscription: "Aviation in itself is not inherently dangerous—but like the sea, it is terribly unforgiving of any carelessness, incapacity or neglect." The company produces high-strength airframe bolts in its new Culver City, Calif., plant.

♦

The Atomic Energy Commission has accepted two proposals from **Bendix Aviation Corp.**, Detroit, and **Tracerlab Inc.**, Boston, to study, at their own expense, the commercial feasibility of manufacturing, processing and selling radioisotopes. The long-range goal of the two projects is wider commercial use of radioisotopes.

♦

Niles Rolling Mill Co., a **Sharon Steel Corp.** subsidiary, is constructing a one bay extension of its galvanizing building, a new two-story stores, laboratory and engineering building, and a new machine shop. Total cost of these improvements is estimated at approximately $335,000.

♦

A new physical testing laboratory for railway engineering development work will be built in Cleveland by **National Malleable and Steel Castings Co.** The engineering laboratory will be one of very few of its kind in the country. Buildings and test tracts will occupy about five acres of land.

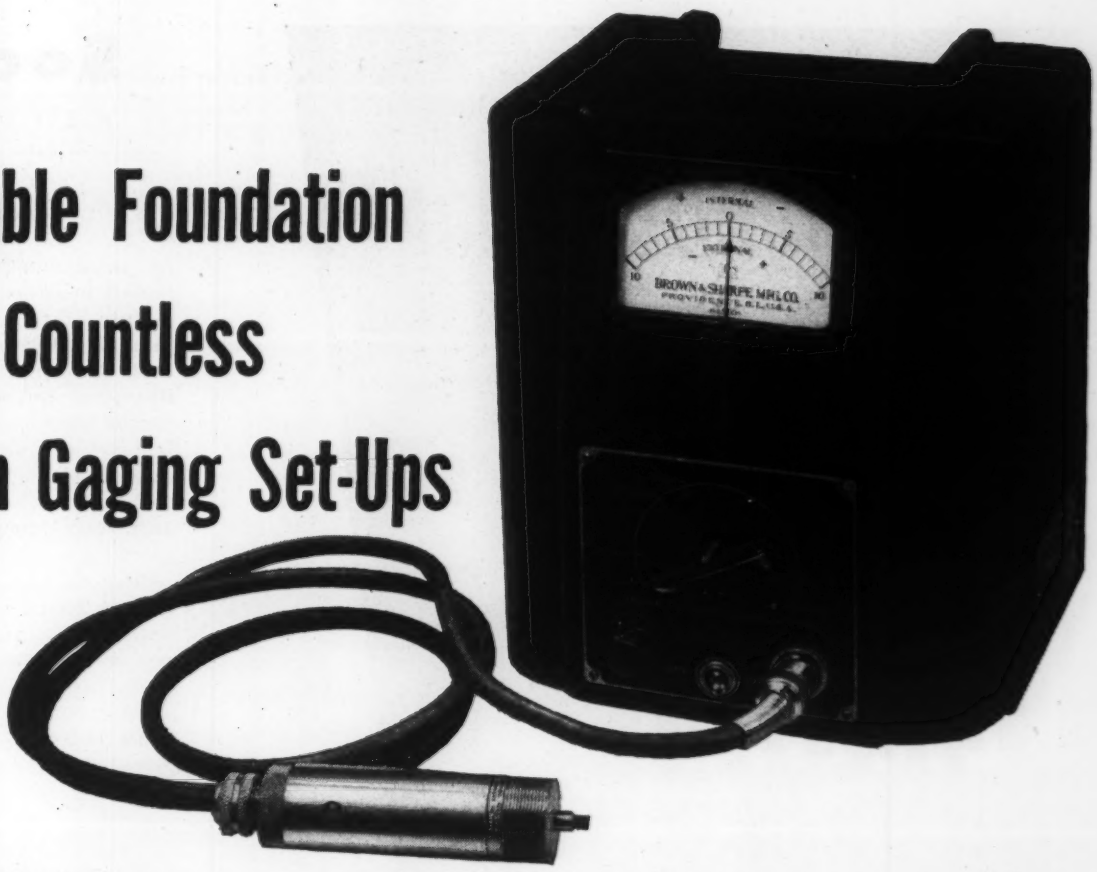
♦

Bowser Inc., Chicago, has acquired ownership of National Scientific Laboratories Inc., Washington, D. C. Research and development contracts with various branches of the Armed Forces held by both companies will be more efficiently performed as a result of the merger, and expansion into new fields will be undertaken.

♦

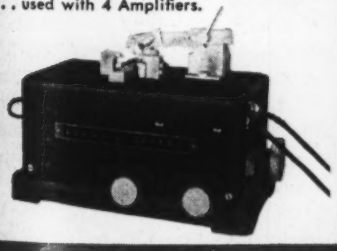
Construction of a new $1,000,000 plant in Van Wert, O., has been announced by **Sterling Electric Motors Inc.**, Los Angeles. The new plant is designed for defense production to expand the company's gear manufacturing facilities for the production of precision gearing systems for the aircraft industry.

Adaptable Foundation for Countless Precision Gaging Set-Ups

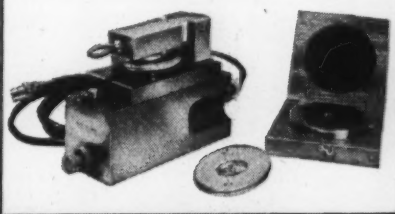


TYPICAL APPLICATIONS

Special gaging fixture made by Brown & Sharpe for inspecting dimensions, side parallelism and side squareness of cutter blades. Employs 4 Gage Head Cartridges . . . used with 4 Amplifiers.



Special gaging fixture, custom-made by Brown & Sharpe, permits gaging of meter valve plate flatness to .00001", when used with Brown & Sharpe Amplifier.



Custom-made fixture, employing Brown & Sharpe Gage Head Cartridge and one Amplifier, measures major and minor I.D.'s of tapered bores; indicates internal angle accuracy.

Brown & Sharpe Gage Head Cartridge and Electronic Amplifier

Here's a really practical basis for versatile precision gaging equipment at reasonable cost.

The Brown & Sharpe Gage Head Cartridge and Electronic Amplifier provide accurate gaging, with direct-reading indications, in units of .0001" to .00001". Simple jigs or fixtures to hold the cartridge for many special gaging jobs can easily be built in your own plant. By shifting the same cartridge among a number of fixtures, you can do precision gaging of practically any length, diameter, or other dimension — with minimum investment in equipment.

Both the Gage Head Cartridge and the Electronic Amplifier are built for severe service conditions. The dustproof, moisture-proof cartridge can be safely exposed to abrasives or coolant. Write for complete literature on this multi-use precision gaging equipment. Brown & Sharpe Mfg. Co., Providence 1, R. I., U.S.A.

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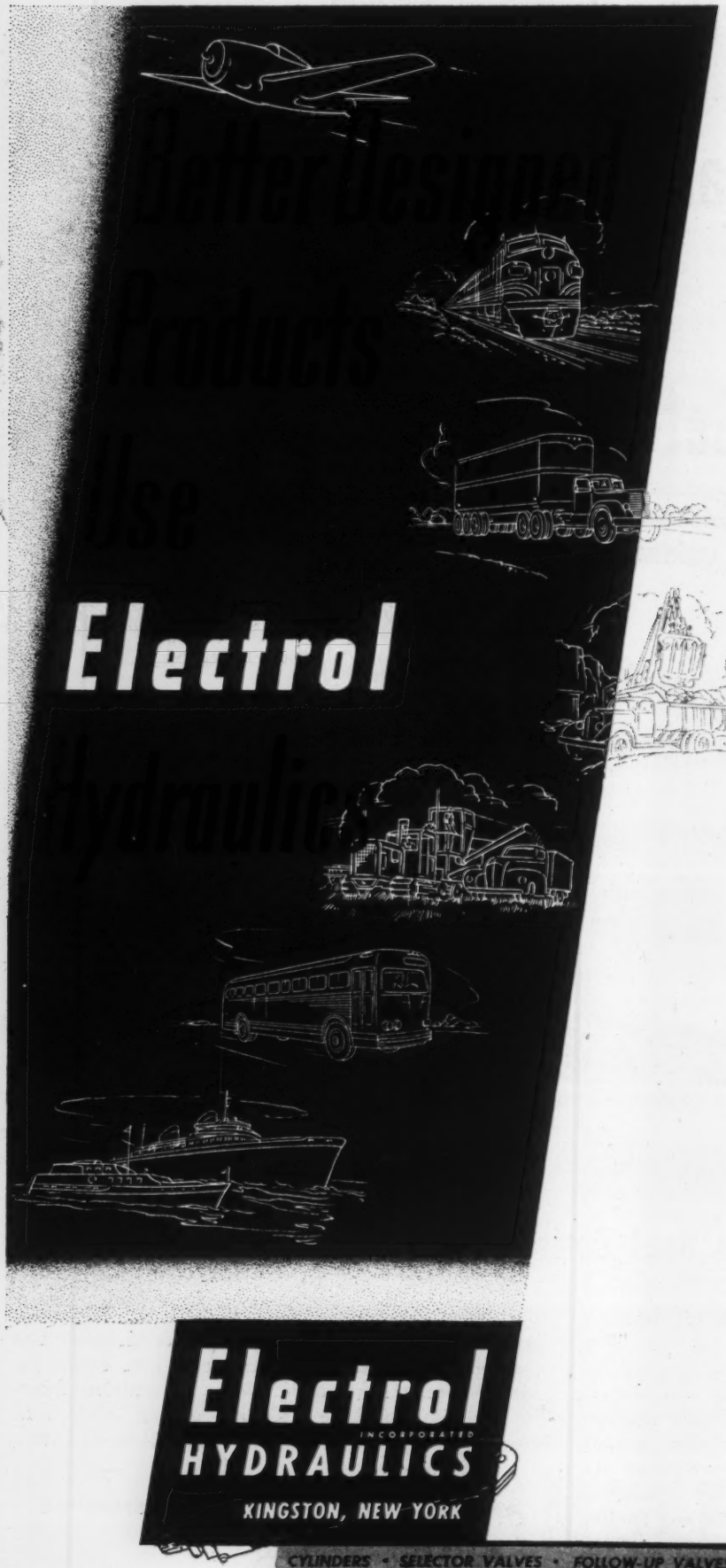
Brown & Sharpe



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CYLINDERS • SELECTOR VALVES • FOLLOW-UP VALVES
CHECK VALVES • RELIEF VALVES • HAND PUMPS
POWERPAKS • LANDING GEAR OLEOS • SOLENOID
VALVES • ON-OFF VALVES • SERVO CYLINDERS • TRANSFER
VALVES • CUT-OUT VALVES • SPEED CONTROL VALVES

Society

ACTIVITIES

SPECIAL Achievement Awards t
time and motion study enginee
for outstanding development of i
proved methods in industry will be
feature of the 15th Annual Nation
Time & Motion Study Clinic to b
held October 31-November 2, at th
Sheraton Hotel in Chicago. Com
panies from all branches of America
industry who annually send represen
atives to the Clinic have been invite
to enter the 1951 competition. Th
Industrial Management Society, whos
research division sponsors the Clini
will grant 1st, 2nd, and 3rd plac
awards in the competition. Selection
will be made on the basis of (1) com
pleteness of the analysis of the prob
lem, (2) resulting benefits to th
company involved, (3) graphic pr
sentation, and (4) stimulation of in
terest in methods improvement.

♦

John C. Cotner, president of th
Hydraulic Press Mfg. Co., Mou
Gilead, O., was recently elected d
rector of the machinery division
the **Society of the Plastics Industrie**
Inc.

♦

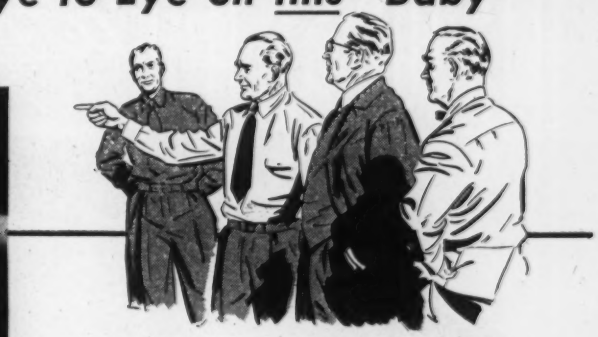
Oliver Smalley, president of th
Meehanite Metal Corp., with offic
in New Rochelle, N. Y., has bee
elected an honorary life member
the **Institute of British Foundrymen**
London, England. This institut
known throughout the world for i
important research and developme
activities in the foundry industr
confers such memberships only in r
cognition of valuable services to th
foundry industry by an individu
over a long period of years.

♦

At its fourth annual summer sym
posium held in Washington, D. C., th
Analytical Division of the **America**
Chemical Society paid tribute to th
National Bureau of Standards
honor of its 50th anniversary. A
the dinner session, the ACS presente
an honor scroll to the Bureau in ap
preciation of the Bureau's work
chemistry and other fields of scienc
and engineering. The presentatio
was made by N. H. Furman, presider
of ACS, to E. U. Condon, Directo
of NBS. The scroll reads:

The American Chemical Society
extends its greeting, congratula-

Maintenance, Production, Purchasing and Front Office can see Eye to Eye on this "Baby"



It's a TOUGH, LONGER-LASTING BULL DOG V-BELT!

Yes, a Bull Dog V-Belt has something for everybody. Your engineers and production heads who have enough on their minds already with shortages and the necessity for increased output will appreciate the SPECIALLY ENGINEERED BWH CORD SECTION and its high tensile strength. They'll get the superior load carrying capacity from BULL DOGS and the ability to absorb shock loads that's needed.

Your maintenance men (engineers, too) will note the QUALITY CONTROLLED COMPOUNDS developed by BWH which run cooler and do not crack or deteriorate under severe flexing. They'll probably note also the MINIMUM STRETCH — due to a new and exclusive technique in processing Bull Dog Cords. They'll be *sure* to note the less slippage, fewer adjustments, longer belt life that results.

Your maintenance men will also okay the Bull Dog V-Belt's DURABLE COVERS. They're made of closely woven, heavy, bias-cut fabric that takes the torturous wearing action where the belt meets the sheave — seals it against the penetration of dirt, grease and moisture.

With it all adding up to less money *out* in belt repairs and replacements and more money *in* from maintained and increased production . . . don't you think Purchasing and the Front Office will be glad to go along?

BWH
DEPENDABLE RUGGEDNESS

TOUGH PROBLEMS INVITED!
Ask us or your nearest BWH distributor about your power transmission belting, conveyor belting or hose problems. We're specialists in making mechanical rubber products work *better, longer.*

Another Quality Product of

BOSTON WOVEN HOSE & RUBBER CO.

Distributors in all Principal Cities

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OIL SEALS

THREE separate and distinct laboratories to solve your sealing problems

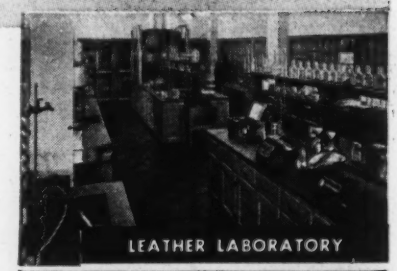
Good packings design requires exact answers to specific hydraulic, pneumatic, or fluid retention problems with rubber or leather.

Supplying these facts is the important function of Trostel research—supplying them out of experience wherever possible; developing new compounds and impregnations where existing materials are found wanting.

The end result is a thoroughly tested design based on known operating data; one that can be produced economically, in quantity, under rigid laboratory control.

We invite you to join the many well-engineered companies who have found these services both indispensable and profitable.

Illustrated bulletin on request.



LEATHER LABORATORY

SYNTHETICS LABORATORY

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ALBERT TROSTEL & SONS COMPANY
Packings Division • Milwaukee 1, Wisconsin
Since 1858

TROSTEL
engineered
PACKINGS

tions and best wishes for the future of the National Bureau of Standards on this 50th anniversary of its establishment and pays tribute to the contributions to chemistry which the Bureau has made in the standardization of materials and methods, in the development of new and improved products, and in basic research. These have been of major importance in this half century of rapid progress of the science, the industry, and the profession represented by this Society.

♦

Through its Research Committee under the chairmanship of C. M. Ashley, Carrier Corporation, the **American Society of Refrigerating Engineers** has recently authorized grants to a number of colleges for research on subjects pertaining to refrigeration. These grants were made under the ASRE policy of sponsoring completely or in part a number of research projects each year. Although the Research Committee recommends the subject and progress reports are submitted semi-annually before each Convention, the colleges are given a completely free hand in regard to the manner in which they conduct the work. At present, eighteen active research projects are being conducted under the sponsorship of ASRE.

♦

Rene D. Wasserman, director of research and president of Eutectic Welding Alloys Corp., Flushing, N. Y., has been appointed to the Research Committee of the **National Association of Manufacturers.**

♦

Glen C. Riegel, chief metallurgist of the Caterpillar Tractor Co., Peoria, Ill., has been named by the **American Society for Metals** to lead foreign and American experts in technical sessions at the World Metallurgical Congress in Detroit, October 14-19. Mr. Riegel is noted for his development of new steel hardening methods. His process of heat applications to metals has cut expensive alloy content in steel and has revolutionized the manufacture of large gears for heavy machinery.

♦

Hugh L. Bills, vice president in charge of industrial relations of the Acme Steel Co., Chicago, will receive the coveted Annual Industrial Relations Achievement Award of the **National Metal Trades Association** at the Association's 52nd annual convention to be held at the Blackstone Hotel in Chicago, November 14, 15,

STANDARDIZE WITH OHIO

Long experience, coupled with most modern equipment, combined with quality materials go into each Ohio Gear and Ohio Speed Reducer. Every detail of product and workmanship is designed to insure accuracy, durability and smooth operation.

The materials regularly used are those which have proved to be most satisfactory for general use under average working conditions. Type of gear, size and nature of application are some of the factors determining the material selected for any given gear. Check for dimensional accuracy is made at each step of manufacture and rigid tests and inspections of the finished gear by experienced shopmen detect any inaccuracy and establish fidelity of specifications in every detail.

In the cutting of Ohio Gears and construction of Ohio Speed Reducers, the components have higher than average strength factors for long life, lower up-keep and operating cost.

Illustrated above are a few applications by large manufacturers who depend on Ohio Gear.

1. Ohio Gear DPL Speed Reducer operating a paint booth turn-table in a large metal working plant.
2. Ohio DS Speed Reducer, 300 to 1 ratio, used in the drive of a machine which automatically welds both heads into the shell of a 55 gallon barrel.
3. Ohio Gear DHU Speed Reducer operating an overhead scrap conveyor belt in a large die casting plant.
4. A PL2 Reducer, 40 to 1 ratio, operating the turn-table of a machine automatically welding automobile crankshaft vibration dampers.
5. Series of Ohio Gear HS Speed Reducers operating conveyors in a California fruit packing plant.
6. Detroit RotoGrate Industrial stoker using an Ohio DHH2 Speed Reducer as part of auxiliary equipment.

Consult your nearest distributor or write us for complete information.

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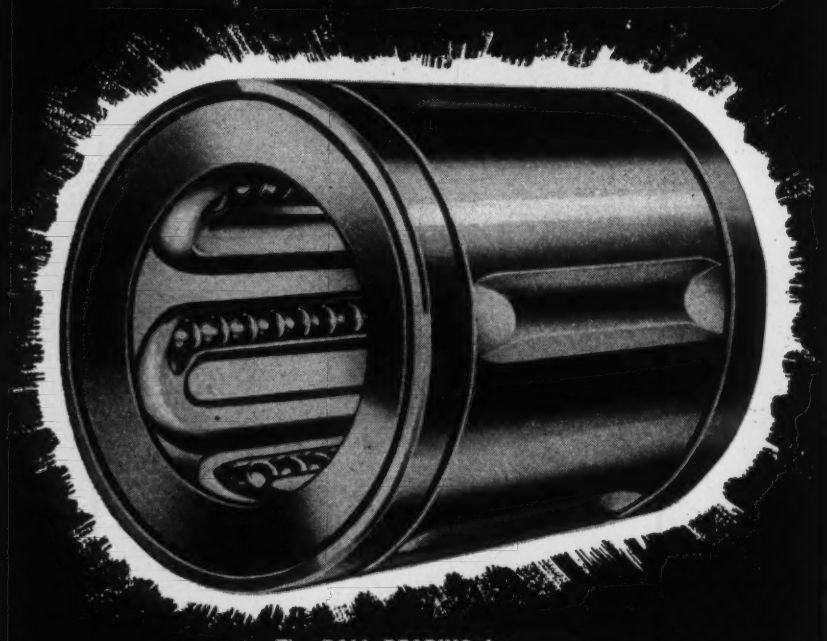
OHIO GEARS

THE OHIO GEAR COMPANY

1338 EAST 179 STREET
CLEVELAND 10, OHIO

BALL BUSHING



The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision *Series A* BALL BUSHINGS.

And now hundreds of original equipment manufacturers use the low cost Commercial *Series B* BALL BUSHINGS which were developed for support of linear motions in competitively priced, volume manufactured products where super precision is not essential.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on *guide rods, reciprocating shafts, push-pull actions,* or for support of *any mechanism that is moved or shifted in a straight line.*

Improve your product. Up-date your design and engineering with BALL BUSHINGS!

LOW FRICTION • LONG LIFE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LASTING ALIGNMENT • LOW MAINTENANCE

Now manufactured for 1/4", 1/2", 3/4", 1" and 1 1/2" shaft diameters.

Write for descriptive literature and the name of our representative in your city

THOMSON INDUSTRIES, INC., Dept. E

MANHASSET, NEW YORK

PROGRESSIVE MANUFACTURERS USE BALL BUSHINGS—
A MAJOR IMPROVEMENT AT A MINOR COST

and 16. Inaugurated at the association's Golden Anniversary in 1949, the award, in the form of an inscribed plaque, recognizes the American citizen whose contributions in the field of Industrial Relations are deemed most important. The Association's Award Committee announced its selection of Mr. Bills on the basis of the following achievements: "For contributions to the fields of merit rating and sound specialist training, for ably interpreting industry to the public and its representatives, for unfailing support and guidance to efforts raising the standards of industrial relations personnel, and for conspicuous success in promoting better labor and human relations."

♦

The National Association of Aluminum Distributors was organized recently to deal with problems arising out of the aluminum industry. Officers of the newly formed trade group are: President, W. W. Doxey, T. E. Conklin Brass & Copper Co.; vice presidents, T. Stenson White, The Nottingham Steel Co., and Ralph W. Shaw, Jr., A. R. Purdy Co.; executive secretary and treasurer, Raymond L. Collier. For the past twenty-two years connected with iron and steel foundry trade associations, Mr. Collier will devote the next few months to a comprehensive survey of the aluminum distributing industry, after which a long-range program of association activities will be laid out to serve as a guide for future operations.

♦

A program to help machine tool manufacturers step up their production by subcontracting the building of either complete machines or component parts has been launched by the **American Society of Tool Engineers.** The aim of the program is to find other manufacturing plants with the capacity and ability to produce machine tools and components and put them in touch with machinery builders seeking added capacity. In announcing the program, Harry E. Conrad, executive secretary of the society, pointed out that the only logical means of rapidly stepping up machine output at present is by the subcontracting. Analysis of plants to determine their ability to produce specific machine tools or parts will be left to the individual machine tool contractor although a preliminary study of facilities available is being made in each case by the headquarters staff of the society, including the editors of the society's publication, *The Tool Engineer.*

More time for creative drafting!

Look at just two of the ways Kodagraph Autopositive Paper saves valuable drafting time for the Cleveland Crane and Engineering Company.

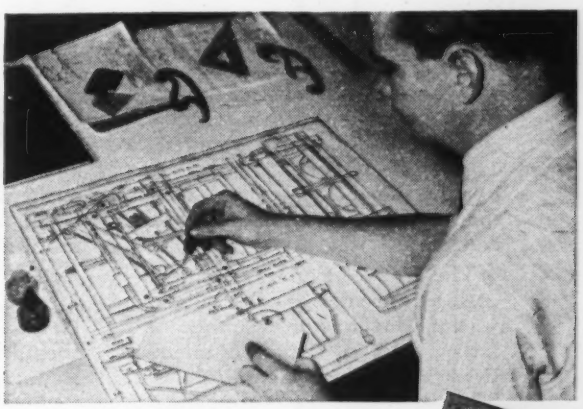
The chances are you'll be able to take similar short-cuts in your work . . . *turn hours of costly retracing time into hours of creative drafting time.*

1 Time saved . . . when drawings must be combined

Many clients order custom jobs requiring electrical components which Cleveland Crane must obtain from outside vendors. Oftentimes, the designs for several of these units must be combined in one drawing before original drafting can begin. This used to be a tedious retracing job—*but no longer.* Now, desired sections of the vendors' prints are reproduced as a composite print on "Autopositive" Paper. Exposure is in a direct-process machine; processing is in standard photographic solutions. The result is a sparkling positive intermediate . . . with dense photographic black lines on a clean, evenly translucent base. On it, the draftsman simply adds the necessary wiring detail . . . producing a new "master" in a fraction of the old time.

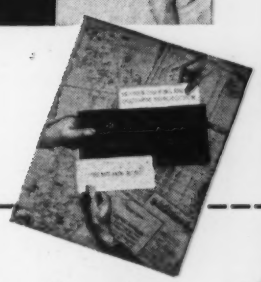
2 Time saved . . . when drawings must be changed

New design must replace old detail on complicated switch assembly drawings. *And Cleveland Crane is doing the job the easy way:* instead of making a new drawing—which would be 85% retracing—they reproduce the original one on Kodagraph Autopositive Paper. Then the draftsman removes the unwanted lines from the intermediate print with corrector fluid . . . and draws in the new detail. Result: a brand-new "original" is ready in three hours instead of 3 days. *Ready* to produce sharp, legible shop prints in the desired number.



Kodagraph Autopositive Paper

"The Big New Plus" in engineering drawing reproduction



- It enables you, or your blueprinter, to produce positive photographic intermediates directly at a new, low cost.
- It enables you to reclaim old, weak-lined drawings . . . reproduce opaque originals and prints.
- It protects your valuable originals . . . produces more legible shop prints.

—MAIL COUPON FOR FREE BOOKLET—

EASTMAN KODAK COMPANY
Industrial Photographic Division, Rochester 4, N. Y.

Gentlemen: Please send me a copy of your illustrated booklet giving all the facts on Kodagraph Autopositive Paper.

Name_____ Position_____

Company_____ Street_____

City_____ State_____

Kodak
TRADE-MARK

Inefficient Government operations
like the Post Office waste billions of dollars every year.
Here's how *you* can help cut this dangerous waste.

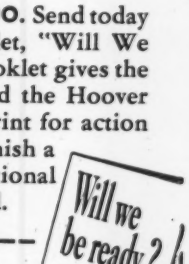
● Why is the Post Office in debt to the tune of $500 million yearly?

The bipartisan Hoover Report showed that no basic change has been made in the organizational structure of this department since 1835—that it costs 20% more to operate the antiquated mail trucks than it does to run a fleet of modern trucks.

The Hoover Report recommendations were designed to wipe out wasteful inefficiency like this. And today, 50% of the recommendations have been enacted into law. They've made a big start in the important job of modernizing Federal machinery. They've cut waste in Government operations by over $2 billion annually.

Now the rest of the Report recommendations are before Congress. If passed, they can save billions more. For example, full enactment of the recommendations as they affect the Post Office would cut in half the postal deficit of $500 million.

HERE'S WHAT TO DO. Send today for the FREE booklet, "Will We Be Ready?" This booklet gives the rousing story behind the Hoover Report. It's a blueprint for action that will help you finish a job on which our National Security may depend.



TEAR OUT COUPON TO REMIND YOURSELF TO GET THIS FREE BOOKLET WITHOUT FAIL

Hoover Report, Box 659, Philadelphia, Pa.

I WANT TO LEARN more about how I can work for "better government at a better price." Please send me your free bipartisan booklet, "Will We Be Ready?"

Name_____

Address_____

This message is published in the public interest

MACHINE DESIGN

SALES AND SERVICE
Personnel

WITH offices in the company's Chicago district office, **John B. Madden** has been appointed hydraulic sales manager for the north central district of A. O. Smith Corp. Formerly product supervisor, Mr. Madden originally operated hydraulic sales from the company's Houston Works where vertical turbine pump manufacturing is centered.

♦

The board of directors of the Charles Beck Machine Corp., Philadelphia, has elected **Milan F. Dudeff** vice president-sales and engineering. He previously served as manager of sales and engineering for the company.

♦

G. F. Vietor Jr. has been appointed a district manager of Air Reduction Magnolia Co., a division of Air Reduction Co. Inc. He will make his headquarters at Houston, Tex., and will have sales responsibility for the Houston district with branch offices at San Antonio, Beaumont and Corpus Christi, Tex. Mr. Vietor first joined Air Reduction in 1939, and after serving in the U. S. Navy, returned to the company, serving in a sales capacity in various cities. He was promoted from assistant manager of the Boston district to his present position.

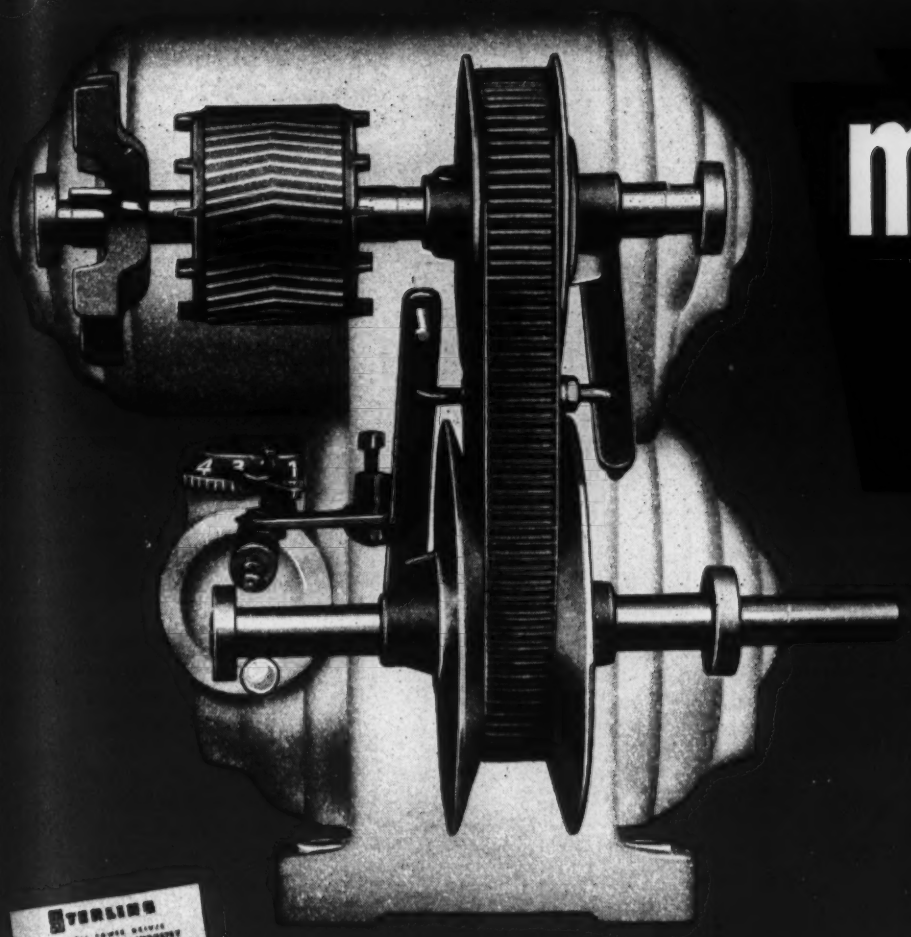
♦

Dan Chapin has been named to the magnesium sales group of the Cleveland office of The Dow Chemical Co. He is a graduate of the company's general training course and a supplementary training course in magnesium.

♦

The Reliance Electric & Engineering Co., Cleveland, has added four sales application engineers, a sales analyst, and two field service engineers to its district offices in six cities. The new sales application engineers and their respective assignments are as follows: **Ralph D. Abercrombie Jr.** has been assigned to the sales office in Buffalo; **Rex T. Willard,** to Atlanta, Ga.; **Merle Kip Sieber,** to the New York office; and **Nicholas D. McKay,** to Detroit. Named to handle a temporary special assignment in a sales analysis capacity at the company's Newark,

power modernization



means

perfect speed control

Ask for your copy of pictorial bulletin No. B-65, showing Sterling Electric Power Drives Turning The Wheels of Industry.

STERLING SPEED-TROL

...GIVES YOU VARIABLE SPEED CONTROL NECESSARY FOR:

PROCESS CONTROL OF: Temperature — viscosity — level — pressure — flow — etc.

TIME CONTROL OF: Baking — drying — heating — cooking — pasteurizing — soaking — chemical action — etc.

EQUIPMENT ADAPTATION TO: Load variation — sequence synchronization. Size — tension — hardness or shape of materials to be processed — machined — conveyed — blended — mixed — etc.

VARIATIONS IN: Quality — quantity — operators' abilities — etc.

OUTSTANDING FEATURES:

Infinite speeds — positive speed regulation — fingertip control — large indicator — positive pulleys — no springs — protected — balanced design — streamlined — Herringbone Rotor — through ventilation — shielded ball bearings — versatile mounting — NEMA dimensions — shock absorbing — quiet operation — rugged — compact — dependable — long life.

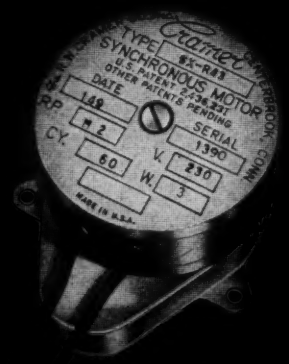
STERLING ELECTRIC MOTORS

Plants: New York 51, N. Y.; Los Angeles 22, California; Hamilton, Canada; Santiago, Chile.

Offices and distributors in all principal cities.

precision built...

Cramer



TYPE SX SYNCHRONOUS MOTOR

A permanent magnet type motor producing an exceptionally high torque, the Cramer Type SX Synchronous Motor is widely used with timing devices, recording instruments, communications equipment . . . and for many other applications throughout the instrument and control fields requiring a constant speed at a given frequency. Self-starting . . . operates at synchronous speed only. Compact . . . precision-built . . . available with output speeds from 60 RPM to 1 24 RPH.

TYPES SCS & SCR CLUTCH MOTORS

Designed to meet the needs of many timing, recording, indicating, and switching applications where an accurate reset operation is essential, Cramer Clutch Motors combine the Type SX Motor and a differential gear drive. Two basic types . . . Type SCS equipped with direct-acting clutch . . . Type SCR with reverse-acting clutch . . . each available in a wide range of speeds.

Cramer motors are also available as Reversible and Chart Drive Types. Write for complete information.

THE R. W. CRAMER CO., INC.

BOX 6, CENTERBROOK, CONN.

Builders of dependable timing devices for more than 25 years.

INTERVAL TIMERS • TIME DELAY RELAYS • RESET TIMERS • CYCLE TIMERS

PULSE TIMERS • RUNNING TIME METERS • PERCENTAGE TIMERS

N. J., office is **John H. Stevens.** The two newly appointed field service engineers are **Cecil D. Wright** and **Charles F. Carnish,** assigned to the Charlotte, N. C., and Detroit offices respectively.

♦

L. Duke Golden has been appointed director of sales education on the administrative staff of The Dayton Rubber Co., Dayton, O. He has had over 23 years of experience in selling, writing and teaching. In his new capacity Mr. Golden will establish and conduct complete sales educational programs for all company sales and service personnel, as well as for the sales personnel of Dayton distributors.

♦

The appointment of **Joseph Emery Edens** as a member of the sales department of Lebanon Steel Foundry, Lebanon, Pa., has been announced.

♦

David E. Gow has been named assistant to **George W. Marshall Jr.,** vice president of asbestos products sales for Raybestos-Manhattan Inc., Passaic, N. J. During his six years with the company Mr. Gow has served as sales manager of the packing division and has been in charge of the United States asbestos division's sales of brake lining and clutch facings to original equipment manufacturers. He will continue to make his headquarters at the company's Manheim, Pa., plant.

♦

Aro Equipment Corp., Bryan, O., has appointed **John F. Young** to the position of division manager for Pittsburgh and western Pennsylvania.

♦

Harold Blumenstein has been named middle Atlantic states sales representative for Prevore Electric Manufacturing Corp., Brooklyn. He will make his headquarters in Philadelphia.

♦

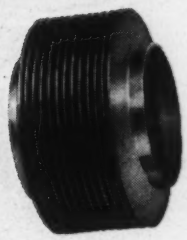
General Electric Co. has announced several apointments in its sales departments recently. **W. F. Rauber,** manager of sales of the switchgear department in Philadelphia, has been named special representative of the large apparatus division in Washington, D. C. Simultaneously, **Clarence E. Burke,** manager of sales of the specialty transformer and ballast department, Fort Wayne, Ind., was appointed to succeed Mr. Rauber in the Philadelphia post. **Edmund C. Schorr** has replaced Mr. Burke in

Now...when production REALLY COUNTS

SAVE TIME with Titeflex

Titeflex *all-metal* flexible tubing can help you *save time* in many operations. Its easy flexibility permits *fast* installation in difficult locations . . . does away with much slow, laborious pipefitting. Its strength helps you overcome quickly dozens of problems involving vibration, flexing and misalignment in conveying liquids and gases.

Titeflex is made in brass, bronze, stainless, Monel and Inconel . . . in types and sizes to handle temperatures to 1550°F. and pressures to 6800 psi. In addition, our engineers will be glad to work with you in developing special types. Write us.



New! Titeflex Bellows

For sealing high pressure valves . . . for absorbing lineal expansion and high frequency vibration in pipe lines. All-welded construction. Made in plain steel, stainless, Monel, Inconel . . . standard sizes 1" to 5" I.D. Plain ends for welding — or supplied with any type of fittings. Write for descriptive literature.

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508 Frelinghuysen Ave., Newark 5, N. J.

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Fast, Efficient, Low-Cost

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for Plant, Lab, Office

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Saves up to 80% of Commercial Blue Print Costs!

● Quickly make accurate black-on-white or blue-on-white prints up to 24" x 36" from translucent originals, at less than 2c per sq. ft. Just p.ug into 115 volt a.c. line. Makes photocopies too. Uses diazo (moist or ammonia dry) process. $155.81 includes initial supply of paper and developing powder. Printer only, $149.81. Shipping weight, 85 lbs. Smaller models from $55.12. *Order the Spee-Dee on 10-days free trial or write for full facts.*

MODEL "D" VERSA-LINER

Volume Production—Prints when Needed

● Economically prints and develops black line and colored line whiteprints. Uses dry ammonia-fume diazo method. Plugs into standard 115 V 60 cycle a.c. line, using 19 amps. Easy to install and operate. Handles cut sheets or roll stock up to 42" wide in any length. Variable speed up to 5 ft. per min. New light source —low replacement cost. Easy to clean. Minimum maintenance. Complete, $1295. Moist diazo-type model at $1095. *Get full facts now.*

PECK & HARVEY

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Manufacturers of Whiteprint, Blueprint and Photocopy Equipment

Fort Wayne. **Clifford M. Dunn** has been named manager of the Michigan apparatus district, succeeding **Arthur R. Hines,** newly appointed assistant manager of marketing for the company. Also, **Paul Stahlberg** of the company's chemical division, has been appointed sales development supervisor of rubber-phenolic molding compounds.

♦

Charles Ebem Wilson, sales vice president of the Worthington Pump and Machinery Corp., Harrison, N. J., has been appointed a West Coast consultant on sales problems. He is retiring from his present duties as well as from the presidency of the Worthington-Gamon Meter Corp.

♦

The Electric Products Co., Cleveland, has announced that **Harold J. Thompson** has joined its Chicago agency. Associated with the Hooper-Green Co., he will specialize in handling the Electric Products line of synchronous and induction motors, a-c and d-c motors and generators, electrolytic power supplies and frequency changers. Mr. Thompson has an extensive engineering and industrial sales background. He was associated with The Reliance Electric & Engineering Co. for over 20 years, serving in various engineering and sales capacities, and was a factory representative for the electrical division of National Acme Co.

♦

Don W. Lyon, district sales manager for Libbey-Owens-Ford Glass Co. at San Francisco, has been named manager of textile sales in the new Fiber Glass division of the company. In his new work Mr. Lyon will have offices in Toledo, O.

♦

Appointment of **Harry W. Jobes** as general manager of the United States Radiator Corp. Metal Products division plant in Chicago Heights, Ill., was announced recently.

♦

New industrial managers have been named for the Denver, Tulsa and Kansas City branch offices of Minneapolis-Honeywell Regulator Co. **W. J. Blackburn** is now industrial manager of the Denver office, succeeding **Donald W. Larcen,** who was recalled to active military duty. Succeeding Mr. Blackburn in the Kansas City office is **Donald D. Baker,** who has been replaced by **Bernard J. Alberts** in Wichita, Kans. **Jack F. Smith** is the new industrial manager at Tulsa, from which city he will co-

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POSITIVE DISPLACEMENT AND IMPELLER TYPES

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FOR TWENTY YEARS— DEPENDABLE, ECONOMICAL, EFFICIENT

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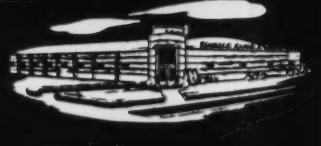

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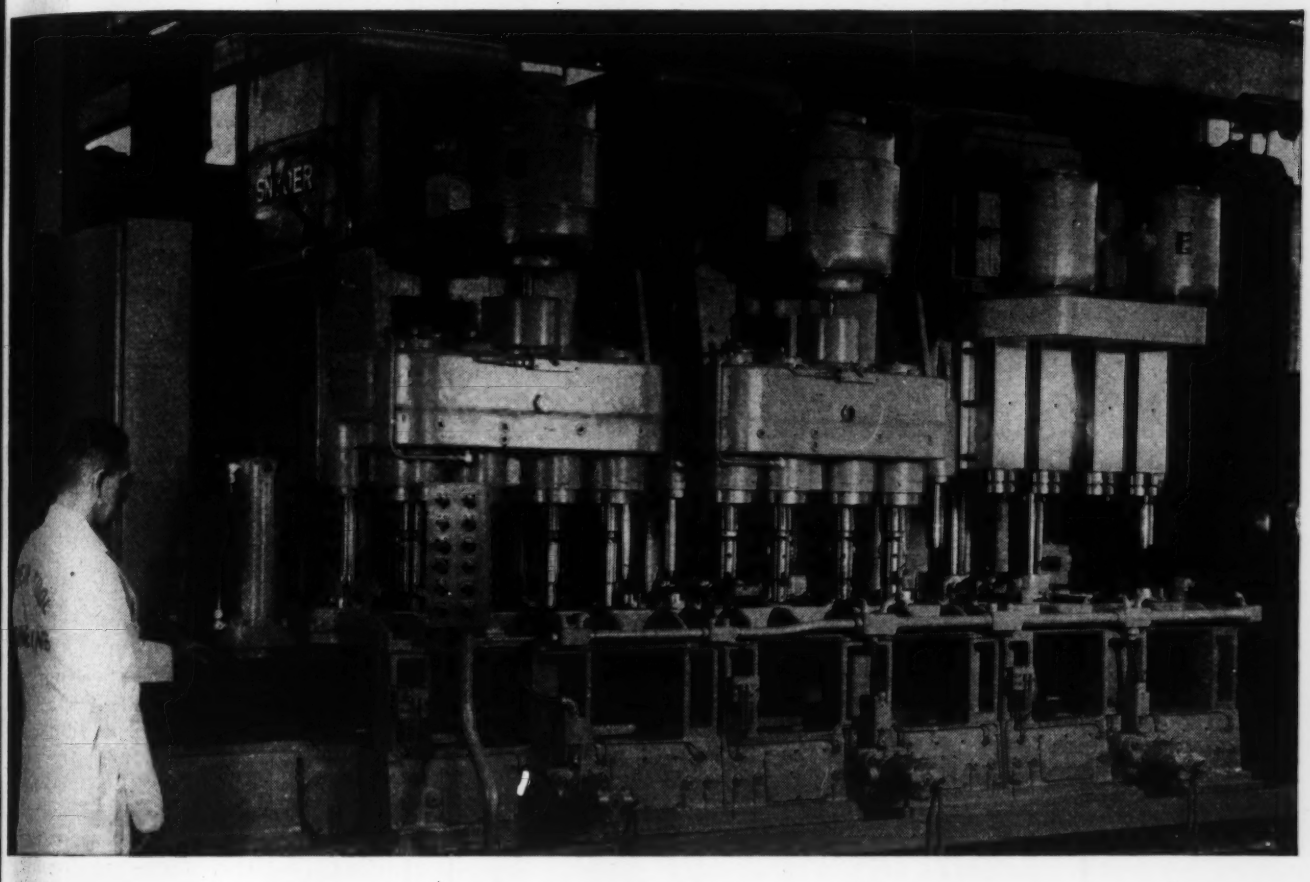
& MANUFACTURING CO., INC.

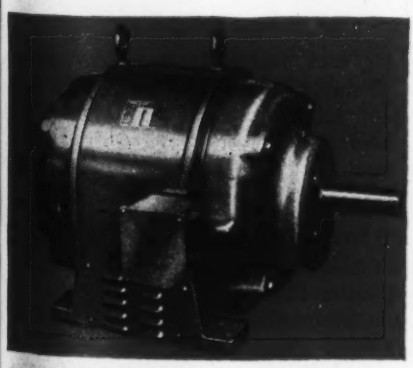
STANDARD OR SPECIAL FOR EVERY MACHINE TOOL AND INDUSTRIAL USE

19652 JOHN R STREET DETROIT 3, MICHIGAN

WRITE FOR CATALOG



Three jobs done, instead of one!



Howell Type F Motor. A high slip, high torque motor designed for punching and boring operations. Sizes ½ to 200 H.P. in open frames; ½ to 125 H.P. in enclosed frames.

Howell Type SC, general purpose, protected-type Motor. Ideal for driving machines and equipment where atmosphere is moisture- or dust-free. Horizontal or vertical mounting.

This 7 station transfer-type boring machine was designed and built to replace *three* machines!

It rough bores, semi-finish bores and finish bores cylinder sleeves to exacting tolerances in one continuous, automatic operation.

Howell engineers worked closely with this manufacturer to provide the right type and size motor for each application. Two 15 H.P. and two 5 H.P. Howell Industrial Motors supply dependable power for the twelve boring spindles. A 7½ H.P. Howell motor operates each of the three hydraulic pumps which control the rough, semi-finish and finish heads. Each motor was engineered for its job!

This is a typical example of the service Howell offers you. We will work with you, both in your plant and at Howell, to design precision-built, quality motors for your jobs.

Our research facilities, engineering experience and manufacturing skill are at your service. May we help you?

HOWELL ELECTRIC MOTORS COMPANY

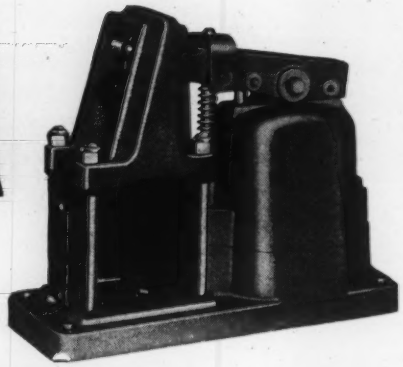
Howell, Michigan

HOWELL Red Band MOTORS

HOWELL ELECTRIC MOTORS CO., HOWELL, MICH.

Precision-built industrial motors since 1915

Quick-As-Wink
AIR AND HYDRAULIC
Control Valves



No. 1491-CS-3
½" 3-Way Solenoid
Operated Air Valve

SOLENOID OPERATED Air Valves

fast, positive, dependable operation

● These valves are widely used for controlling single action air cylinders, clutches, etc. Can be operated with a variety of power switches, mercoid switches or automatic contact switches activated by moving objects. Stainless steel push-pull rods, brass sleeves and U-packings expanded by pressure and all enclosed against dirt, assure long, efficient, trouble-free operation. No metal to metal seating. Precision made. Individually tested. Spring or double solenoid return. ⅜" to 1½" sizes: 2-way, 3-way and 4-way actions. *Write for full details.*

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Control Valves

Hand, Foot, Cam, Pilot, Diaphragm and Solenoid Operated

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SMALL PARTS FOR DEFENSE

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SMALLNESS UNLIMITED

Complicated designs produced in
ONE AUTOMATIC OPERATION

Avoid waiting for scarce prefabricated materials; eliminate scrap loss. GRC delivers small parts faster, more economically. Simple or intricate parts produced in one automatic operation—completely trimmed, ready for use. 100,000 pieces to many millions.

Write, wire, phone for bulletin and samples; or send prints for quotations and delivery dates.

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ordinate the company's industrial sales activities in the Tulsa, Oklahoma City and Amarillo areas under the direction of **Reginald Walker**, branch manager. **Pilgrim McRaven** will handle industrial interests in Oklahoma City.

◆

Harry M. Birns, former sales engineer of the Diamond Machine Tool Co., Los Angeles, has rejoined the company's sales staff.

◆

Formerly sales representative in the New York-New England area for King Fifth Wheel Co., **N. O. Berggren** has been appointed executive vice president while company president A. S. Martin is serving with the United States Army.

◆

The Wagner Electric Corp., St. Louis, manufacturer of motors, transformers and industrial and automotive brake products recently announced the appointments of two new branch managers in the electrical division. **M. B. Atkinson** became manager of the Detroit office, succeeding **R. L. Wells**, who has retired. **A. W. Maas** was appointed manager of the San Francisco electrical office succeeding **E. D. Pike**, who also retired.

◆

A specialist on problems of welding and design of porcelain enamel products, **Joseph F. Janecke** has been appointed manager of the new products division of Ferro Corp., Cleveland.

◆

Hyatt Bearings division, General Motors Corp., has announced the appointment of **Frank H. Webster** as assistant manager of the western division, Chicago. Mr. Webster joined the organization in 1925 as a sales engineer in the Oakland, Calif., office. In 1938 he was transferred to Chicago where he continued in the capacity of sales engineer until his new assignment.

◆

Elevation of **Paul W. Arnold** and **Richard A. Geuder** to new responsibilities in the company's general sales organization has been announced by The Reliance Electric & Engineering Co. Mr. Arnold, who has served as manager of product sales for the past several years, moves up to the newly created post of executive assistant to the sales vice president. Mr. Geuder, who has headed the company's application engineering work since 1944, is now manager of a new

department of applied engineering and industry sales, the latter representing a consolidation of other specialized activities, including contract sales, federal and marine sales, and general industry applications.

◆

Ransford V. Mann Jr. has been appointed Los Angeles district sales representative for the Alloy Tube division, The Carpenter Steel Co.

◆

With training and practical experience in product development, designing and processing, resistance welding and electronics, **Herb Weightman** has been assigned to head the Progressive Welder Sales Co. of California, Burbank, Calif.

◆

Brainard Steel Co. has appointed **Harry W. Hughes** as West Coast manager, with offices in San Francisco. He will be in charge of sales for the Brainard steel strapping system, electric welded mechanical tubing and building products. The company has also announced that **John P. Stitt** has been named district sales manager in Cleveland. He previously served as representative in the Buffalo district and is succeeded there by **James O. Tavenner,** formerly in the main office in Warren, O.

◆

Paul L. Wright has been appointed sales manager of the Buffalo plant of Joseph T. Ryerson & Son Inc., steel distributors. Mr. Wright first became associated with the company at its Chicago plant in 1939.

◆

Announcement has been made by Bolta Products Sales Inc., manufacturer of Boltaron moldable plastic sheet stock, that **Tom Drabek** has been appointed to the post of Midwest division sales manager in Owosso, Mich.

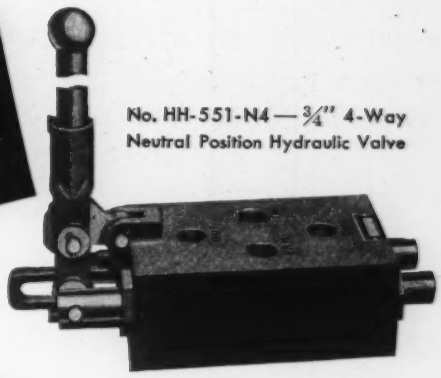
◆

The appointment of **Pierre S. du Pont 3rd** as assistant director of sales of the rubber chemicals division, organic chemical department, has been announced by E. I. du Pont de Nemours & Co. Inc. Mr. du Pont joined the company in 1934 and has been Manager of rayon tire yarn sales since 1947.

◆

Associated with the company in engineering and sales capacities since 1947, **William C. Goeckel** has been appointed to the post of assistant sales manager for Snyder Tool & Engineering Co., Detroit.

Quick-As-Wink
AIR AND HYDRAULIC
Control Valves



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For water or oil hydraulic systems to 5000 p. s. i.

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THE HIGHER THE PRESSURE THE TIGHTER THE SEAL

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Hand, Foot, Cam, Pilot, Diaphragm and Solenoid Operated

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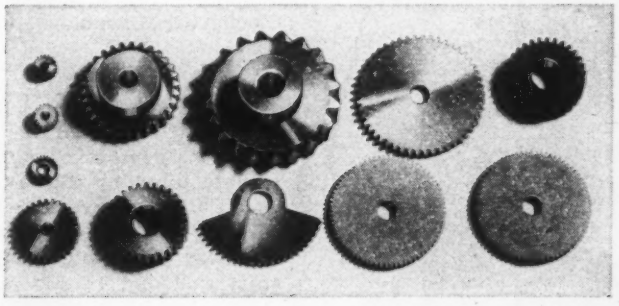

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Rynel precision methods start with accurately formed blanks in our own gear blanking department. Tooth form, accuracy and finish are carefully controlled every step of the way. Gears are cut by experienced gear men on precision equipment of the latest design, and checked by skilled gear inspectors. • That's why engineers and designers know Rynel Gears produce smooth, silent, dependable performance.

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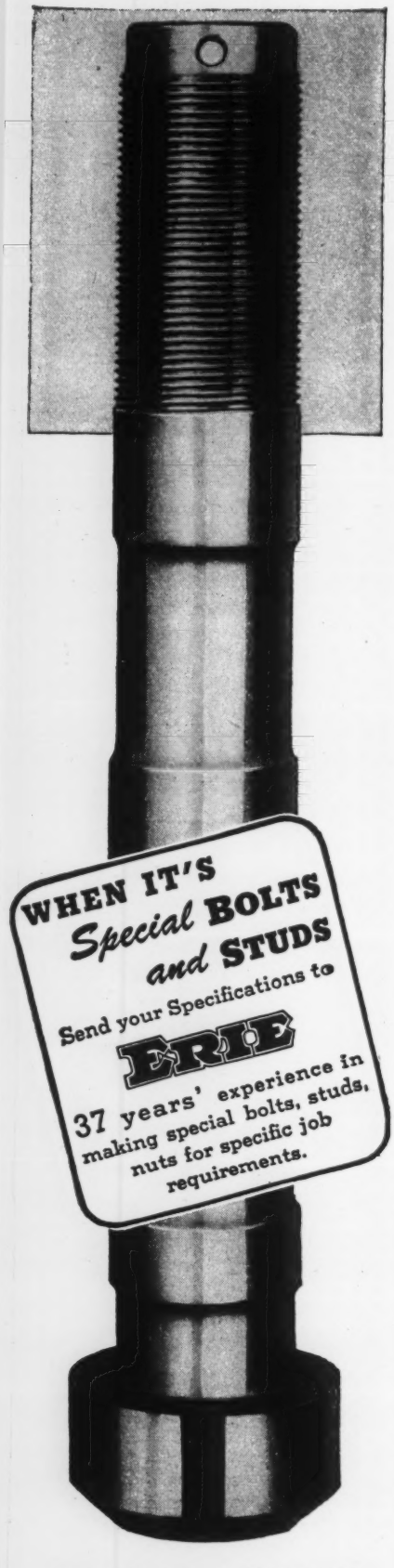

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A SUBSIDIARY OF
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Steelwright to the Nation

REPRESENTATION IN PRINCIPAL CITIES

SALES Notes

IMPROVED sales service for users, fabricators and distributors of seamless and welded stainless alloy and carbon steel tubing will be offered through new sales headquarters recently opened in the Lawson-Chipman Bldg., 1111 Wilshire Blvd., Los Angeles, by **The Babcock & Wilcox Tube Co.**

♦

The Cleveland branch sales office and warehouse of **Reeves Pulley Co.** has been moved to 6408 Euclid Ave., Cleveland 3, O. J. H. Gepfert is manager of this office.

♦

A midwestern department, comprising the states of North and South Dakota, Minnesota, Michigan, Wisconsin, Indiana and parts of Illinois, Ohio, Iowa and Kentucky, has been established by Federated Metals division of **American Smelting and Refining Co.** John W. Kelin has been appointed midwestern sales manager and will direct the activities of the entire midwestern sales organization with headquarters at Whiting, Ind., and district sales offices at Detroit, Cincinnati, Milwaukee and Minneapolis.

♦

Air Associates Inc., Miami, Fla., has been appointed distributor for precision synthetic rubber O-rings manufactured by **The Parker Appliance Co.,** Cleveland. The O-rings will be stocked in a variety of types and sizes for immediate service for aircraft fuel and hydraulic sealing installations.

♦

A new office and warehouse has been opened at 5815 Clinton Dr., Houston 1, Tex., by **Wall Colmonoy Corp.,** Detroit.

♦

Flexitallic Gasket Co., Camden, N. J., has added six new agents and one new distributor to its field organization. The new agents are **Jno. D. Hiles Co. Inc.,** Pittsburgh, serving western Pennsylvania and eastern Ohio and portions of West Virginia; **Engineering Products Co.,** Charleston, W. Va., serving eastern Kentucky and part of Ohio; **Chapman Engineering Sales Co.,** Cincinnati, representative for southwestern Ohio and northern Kentucky; **De Haven Engineering Co.,** Indianapolis, to serve Indiana and western Kentucky; **Steel & Engineer-**

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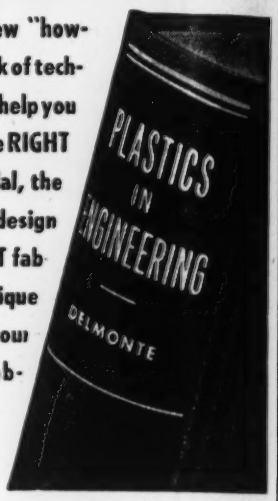
This brand new "how-to-do-it" book of technical data will help you determine the RIGHT plastic material, the RIGHT mold design and the RIGHT fabricating technique to solve your plastics problem.



"Plastics in Engineering" by John Delmonte is not an elementary text. It's an important working "tool" for everyday reference by designers, engineers and users of plastics.

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You'll have scores of up-to-the-minute facts about plastics right at your fingertips: How strong various plastics are—for what uses they are best suited—how to design plastic parts—how these remarkable synthetic materials are molded, extruded, laminated, cast—how much heat they will stand—how to guard against failure—how to machine plastics and other vital factors that are so essential to satisfactory plastics performance.

Over six-hundred pages, fully illustrated with photographs, detailed drawings and tables, cover every phase of the plastics industry from raw material to finished product. From its first chapter which dips into the intriguing history and development of the plastics industry, to the last chapter which reveals the primary cost factors in producing plastics, it covers its field thoroughly and authentically.

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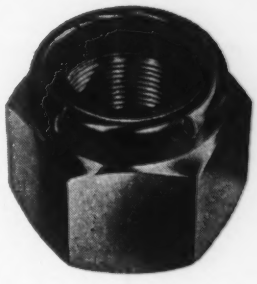
ELASTIC STOP NUTS
Guarantee Tight Fastenings

Rough terrain and rough handling are hazards to the world famous military 'Jeep'. That's why Willys builds its 'Jeeps' and other vehicles with Elastic Stop Nuts at important points to eliminate fastener failures due to vibration.

In this vehicle the famous Red Locking Collar of the Elastic Stop Nut holds firm against vibration—reduces maintenance—on vital applications such as: accelerator hinge, universal joints, body hold down, spring shackles, radiator hold down, and air cleaner. The Red Collar grips bolt threads firmly—protects against vibration, impact, and stress reversal—prevents freezing of nuts to bolts by protecting internal bolt threads against corrosion.

Check the advantages of Elastic Stop Nuts against any other type of self-locking fastener. You'll find that only ESNA offers a complete line of thread sizes and varied nut types engineered to simplify your assembly line fastening problems and to provide your customers with maintenance-free operation.

Whether you are manufacturing equipment for rough military use or designing better performance and easier maintenance into equipment for your normal market . . . use vibration-proof fasteners. Now is the time to get full information. Write for complete product line bulletin to Elastic Stop Nut Corporation of America, 2330 Vauxhall Road, Union, N. J.



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THE FAMOUS RED ELASTIC COLLAR IS VISIBLE EVIDENCE OF LOCKING SECURITY

Threadless and permanently elastic, it provides these 4 outstanding features:

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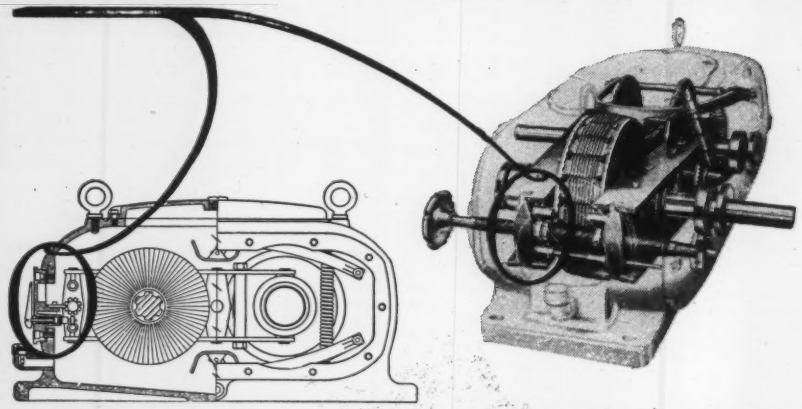
ELASTIC STOP NUTS

DESIGN HEADQUARTERS FOR SELF-LOCKING FASTENERS

Mass. G&T Gear

Applied in P.I.V. Variable Speed Drive



Speed changes on the LINK-BELT P.I.V. Variable Speed Drive are shown by means of a rack and pinion, furnished by "Mass. Gear," which connects directly to speed setting indicator. Close speed selection, resetting and readings are assured by the accuracy of these gears.

Your gear problem can be promptly and effectively handled by consulting Massachusetts Gear & Tool Co., Woburn, Mass. Write for free illustrated literature.

Massachusetts Gear & Tool Co.

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This large manufacturer of home laundry equipment wants immediately:

RESEARCH DIRECTOR . . . with ability to head product research laboratory. Must have experience in supervision and familiarity with materials, testing, and production procedures in home laundry or related fields.

MACHINE DESIGNERS . . . experienced in product development in home development in home laundry or related fields and familiar with production requirements.

If you can fill one of these jobs—and would like a salary in line with your education and background . . . plus participation in outstanding bonus plan and supplementary benefits . . . and an opportunity to live in a community considered the ideal vacation spot by thousands . . . *send up your experience record now.* We'll give you a prompt reply and arrange an early interview if your record indicates that you'll meet our requirements. Write to J. M. Ranum.

WHIRLPOOL CORPORATION

203 N. State Street St. Joseph, Michigan

ing Products Co., El Paso, Tex., for southwestern Texas, southern New Mexico and Arizona; and **Energy Control Corp.**, Philadelphia, serving eastern Pennsylvania, southern New Jersey and Delaware. **Fleck Bros. Ltd.**, Vancouver, B. C., is the new distributor appointed to serve the western provinces of Canada.

♦

Metals Disintegrating Co. Inc., Elizabeth, N. J., has announced the appointment of **The Roy A. Ribelin Distributing Co.**, M. & M. Bldg., Houston, Tex., as distributor in southeastern Texas.

♦

Establishment of a regional sales office and warehouse in Dallas, Tex., has been announced by the **Minnesota Mining & Manufacturing Co.** Designed to permit better service to customers in Texas and neighboring states, the new facilities are located at 1221 Dragon St.

♦

The Whitney Chain Co., Hartford, Conn., has announced removal of its district sales office to new and larger quarters at 70 Dorman Ave., San Francisco, Calif. The new headquarters will function as the engineering sales outlet for the complete line of Whitney power transmission and conveying chain, couplings and sprockets in the San Francisco and northern California regions.

♦

Rodney Hunt Machine Co. has moved its southern regional office from Greenville, S. C., to Room 909, Wilder Bldg., 237 S. Tryon St., Charlotte 2, N. C.

♦

The De Laval Steam Turbine Co., Trenton, N. J., has announced the completion of a new building at 160 Folsom St., San Francisco, Calif., which will be the company's new San Francisco headquarters for sales and service activities. Besides providing increased warehousing facilities for standard centrifugal pumps, IMO pumps, speed reducers and flexible couplings, the new building will also permit faster handling of repair and service orders for western customers.

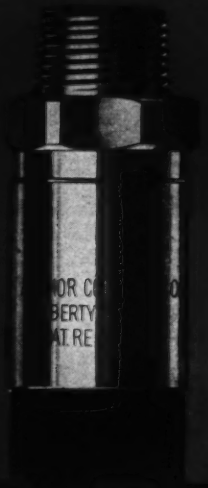
♦

The Canadian operations of **Wheelco Instruments Co.**, Chicago, will now be handled by its new Canadian subsidiary, **Wheelco Instruments of Canada Ltd.**

♦

Simmonds Aerocessories Inc. has opened a new branch office in the Interurban Bldg., Dallas, Tex., to handle the expanding volume of aviation business in the southwest area.

Stop High-Pressure Leaks and Blow-offs



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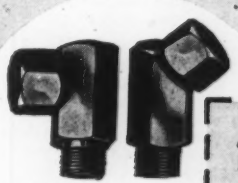
Clamp-type Couplings

2-Piece Re-usable Couplings

NPTF Straight Adapter Unions



45°-90° Adapter Unions

Other styles of related fittings available for piping installations

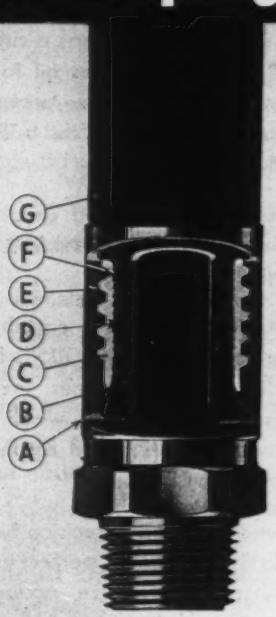
ANCHOR COUPLING CO. INC.

Factory: Libertyville, Illinois • Branch: Detroit, Michigan

Factory application of Anchor's exclusive Ductile Sleeve Coupling is your best insurance against leaks or blow-offs. Our superior grip gives you a plus margin of safety and a minimum time loss due to lay-up of equipment.

Here's how it works (referring to the illustration): Cover stock (G) is removed from the hose by grinding and buffing. Ductile Sleeve (C) is slipped on the end of the hose over the bare wire. Coupling body (A) with steel insert (B) attached is placed in position on the hose. The coupling is then swaged radially on the hose, imbedding the ductile sleeve into the internal grooves of the coupling shell (E) and into the mesh of the wire braid reinforcement (F). This is the exclusive Anchor patented grip.

Some of the applications of Anchor high-pressure flexible oil lines include high-pressure riveting, road machinery, snow plows, coal mining machinery, material handling machinery, machine tool applications, agriculture, railroads, oil field machinery, liquefied petroleum gas, lubrication and various other installations.



Send for complete information on Anchor assembled hose units.

Clip coupon to company letter head —and mail TODAY!

ANCHOR COUPLING CO. INC.
Dept. MD101, Libertyville, Illinois

I want engineered-information on cost-cutting Anchor Ductile Sleeve Hose Couplings. Please send me Bulletin No. 48.

Name..... Position.....

Company.....

Company Address.....

City..... ( ) State.....

D-2

This Electronic Meter

installed in an air conditioned room operates in an oil bath. It has a circulating oil system which allows oil to flow constantly over the balls preventing temperature changes while the balls are measured.

It is used to control and check size, gauge and sphericity of Steel Balls from the Gauging Department.

This electronic meter is capable of measuring as fine as .000005". In the glass vials are master balls, the size, gauge and sphericity of which have been accurately determined by the use of the Johansson Blocks.

Whenever you need precision balls of extremely fine tolerances, perfect surface finish, sphericity and size accuracy—specify Universal Precision Balls. They reduce friction, wear and maintenance costs to an absolute minimum. All Universal Balls are 100% inspected and individually gauged.

UNIVERSAL BALL CO.

PRECISION BALLS OF CHROME AND STAINLESS STEEL, BRONZE AND SPECIAL METALS.

WILLOW GROVE, Montgomery County, Pa.
Telephone, Willow Grove 1200

Meetings

AND EXPOSITIONS

Oct. 14-19—

American Society for Metals, second annual meeting to be held at Hotel Book Cadillac, Detroit, Mich. Additional information may be obtained from society headquarters at the Hotel Book Cadillac, Detroit, Mich.

Oct. 15-19—

American Society for Metals. Thirty-third annual metal show to be held at the Michigan State Fair Grounds, Detroit, Mich., under the sponsorship of the American Society for Metals; American Welding Society; Metals Branch, American Institute of Mining and Metallurgical Engineers; Society for Non-Destructive Testing. Additional information may be obtained from society headquarters, National Metal Congress & Exposition, 7301 Euclid Ave., Cleveland 3, O.

Oct. 19-20—

American Society of Tool Engineers. Regional meeting to be held at the Hotel Vendome, Evansville, Ind. Additional information may be obtained from Society headquarters, 10700 Puritan Ave., 21, Detroit, Mich.

Oct. 22-24—

American Standards Association. Thirty-third annual meeting and second annual national standardization conference to be held at the Waldorf-Astoria Hotel, New York, N. Y. Vice-Admiral George F. Hussey Jr., 70 East 45th St., New York 17, N. Y. is managing director.

Oct. 29-30—

Society of Automotive Engineers. Diesel engine meeting to be held at the Drake Hotel, Chicago, Ill. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary and general manager.

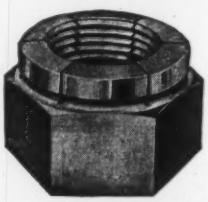
Oct. 29-31—

Society of Automotive Engineers. Transportation meeting to be held at the Knickerbocker Hotel, Chicago, Ill. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary and general manager.

Nov. 1-2—

Industrial Management Society. Fifteenth annual time, motion study and management clinic to be held at the Sheraton Hotel, Chicago, Ill. Additional information may be obtained

FLEXLOC®



SELF-LOCKING NUTS

Help PTC to "KEEP 'EM ROLLING"!

Every day thousands of Philadelphians depend on Philadelphia Transportation Company buses. To "keep 'em rolling," PTC's maintenance must be constant and thorough, since minor failures often cause major breakdowns.

For example, the hex nuts on bus rear axle flanges were being loosened by vibration, despite periodic inspections. Sheared studs resulted. Replacements were expensive, disrupted schedules and loss of riders' goodwill even more so. PTC tried FLEXLOC Self-Locking Nuts, found them a simple, economical solution to the problem.

FLEXLOCs stayed *tight*, eliminated shearing of studs. Yet FLEXLOCs were easy to remove when necessary, could be re-used again and again. Furthermore, FLEXLOC *dependability* reduced the number of maintenance checks needed, effecting additional savings.

If you have to contend with vibration in your business, try FLEXLOC Self-Locking Nuts—free! Just tell us the size, and we'll gladly send samples.

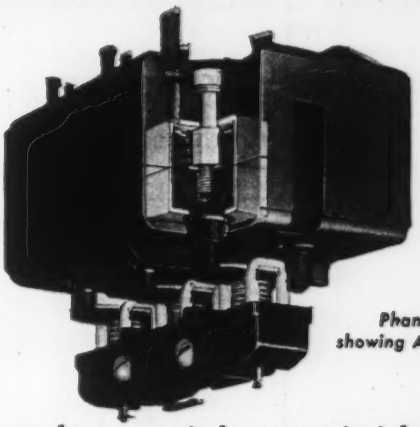
SPS STANDARD PRESSED STEEL CO.
JENKINTOWN 18, PENNSYLVANIA

It's All NEW! TYPE AC Motor Starter

...with the sensational NEW multi-turn magnetic blowouts...

...and TWIN-BREAK CONTACTS

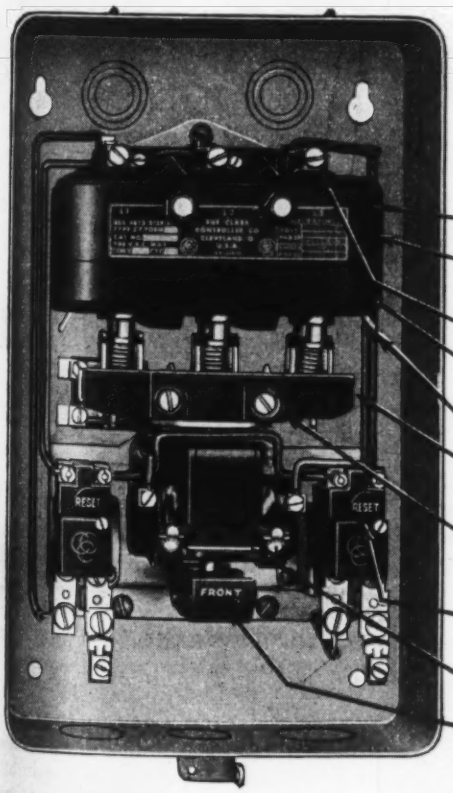
Here, for the first time is a rugged AC magnetic starter that provides the extra protection and dependable operation of "Mill-Type" heavy-duty construction and design.



Phantom view showing Arc-shield

another CLARK FIRST!

Type "CY" starters employ an entirely new principle of arc interruption. The arc is extinguished by the effect of the blow-out coil, *concentric with the contact*. The magnetic field quenches the arc either by lengthening or confining it. In its *forced rotation* it moves continually from a hot to a cold spot—minimizing burning or pitting of contacts. The ingenious design of the arc chamber prevents carbonization and the accumulation of hot gases between wiring terminals—minimizing phase-to-phase failures*.



Open View

- One piece upper arc shell protects terminals from hot gases
- Magnetic arc interrupters with steel arc chambers
- Pressure type terminals line and load
- Arc shields of inorganic non-carbonizing material
- Finger clips for easy contact inspection
- Silver double break control circuit contacts
- Captive screws in contact arm
- Melting alloy type overload relays
- Easy coil replacement—only two screws and one pin to remove
- Vertical lift magnet with steel guide uses no springs

The Maintenance Man's Dream!

- **No filing, dressing or cleaning of contacts!**
- **No tools necessary to inspect contacts!**
- **Easy to change moving contacts!**
- **Stationary contacts changed quickly!**
- **Remove only two screws and one pin to change coils!**
- **Remove only four screws to take out stationary magnet frame!**
- **Power circuit contacts available with springs in complete packaged service kits for ease in stocking!**

*Magnetic blow-out coils are used on all size 2 and 3 Type "CY" starters. The same Mill-Type construction is used on sizes 0 and 1.

Let a CLARK application engineer show you what this new line of CLARK "CY" starters means to you in increased production and lower maintenance.

THE CLARK CONTROLLER CO.

ENGINEERED ELECTRICAL CONTROL • 1142 EAST 152ND STREET, CLEVELAND 10, OHIO

POWER ADVANTAGE in the Top Bracket Power Range . . . V-Type 4-Cylinder WISCONSIN *Air-Cooled* ENGINES, 15 to 30 hp.

These 4-cylinder, V-type Wisconsin Engines meet every heavy-duty power requirement. V-type design assures not only the smoothest power delivery but also represents substantial reductions in engine weight as well as extreme compactness . . . at no sacrifice of rugged construction.

CONDENSED SPECIFICATIONS

MODELS		VE4	VF4	VP4D
Bore	inches	3	3¼	3½
Stroke	inches	3¼	3¼	4
Displ. cubic inches		91.9	107.7	154
H.P. and R.P.M. range		15 at	17.5 at	26.8 at
		1600	1600	1600
		21.5 at	25 at	31 at
		2400	2400	2200
Net weight in lbs., Standard Engine		295	295	410

Our engineering department will gladly cooperate with you in adapting Wisconsin Engines to your requirements. Write for detailed data and the name of the nearest Wisconsin distributor.

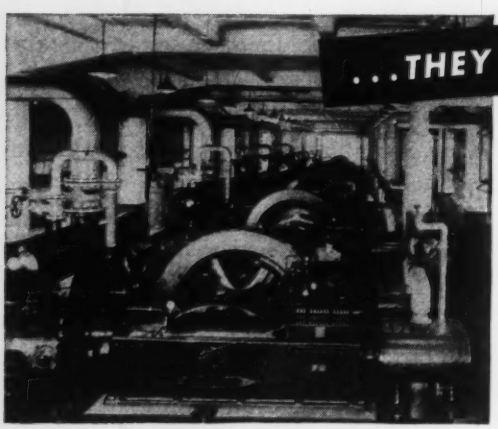
WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

MILWAUKEE 46, WISCONSIN

LEADING PUMPS AND COMPRESSORS HAVE

Manzel **FORCE FEED LUBRICATORS**



Worthington Compressors in an automobile plant, with Manzel Model 94 Lubricators

. . . THEY NEVER FORGET

● Manzel lubricators supply each wearing point with exactly the amount of oil it needs, and *no more.* Thus they reduce oil consumption as much as 90%.

"Manzels" are furnished as standard equipment on leading makes of engines and machinery. Or they can be installed on your present equipment.

We will gladly have a Manzel lubricator engineer submit recommendations without obligation.

Just write . . .

Why it Pays to Select Manzel Lubricators

- THEY LENGTHEN THE LIFE OF MACHINERY
- THEY ARE AUTOMATIC AND TROUBLE-FREE
- THEY ELIMINATE "DOWN TIME"
- THEY CORRECTLY LUBRICATE EACH POINT

Manzel

276 BABCOCK STREET
BUFFALO, NEW YORK

from Society headquarters, 35 E. Wacker Drive, Chicago 1, Ill.

Nov. 7-9—

The American Society of Body Engineers. Sixth annual technical convention to be held at the Rackham Memorial Bldg., Detroit, Mich. Additional information may be obtained from Society headquarters, 100 Farnsworth Ave., Detroit 2, Mich.

Nov. 8-9—

National Conference on Industrial Hydraulics. Seventh annual meeting to be held in Sherman Hotel, Chicago, Ill. Sponsors are the Graduate School of Illinois Institute of Technology and Armour Research Foundation of Illinois Institute of Technology. Co-operating societies are the local sections and chapters of American Society of Civil Engineers, American Society of Mechanical Engineers, Society of Automotive Engineers, American Society of Lubricating Engineers, American Institute of Chemical Engineers, Institute of Aeronautical Sciences, American Society of Agricultural Engineers, Illinois Society of Professional Engineers, and Western Society of Engineers.

Nov. 19-20—

National Metal Trades Association. Fifty-second annual convention to be held at the Palmer House, Chicago, Ill. Additional information may be obtained from Society headquarters, 122 S. Michigan Ave., Chicago 3, Ill.

Nov. 25-Dec. 30—

American Society of Mechanical Engineers. Annual meeting to be held at the Chalfonte-Haddon Hall, Atlantic City, N. J. C. E. Davies, 29 W. 39th St., New York, N. Y. is secretary.

Nov. 26-Dec. 1—

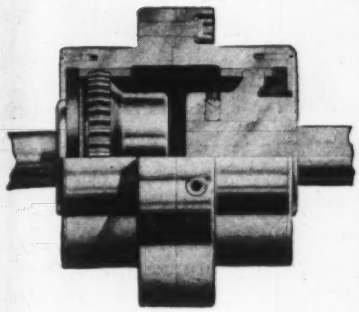
Exposition of Chemical Industries. Twenty-third exposition to be held in Grand Central Palace, New York, N. Y. Charles F. Roth, Grand Central Palace, 480 Lexington Ave., New York 17, N. Y. is manager.

Nov. 28-30—

Society for Experimental Stress Analysis. Annual meeting and exhibit to be held at the Bellevue-Stratford Hotel, Philadelphia, Pa. W. M. Murray, P.O. Box 168, Cambridge 39, Mass. is secretary-treasurer.

Dec. 17-19—

American Society of Agricultural Engineers. Winter meeting to be held at the Stevens Hotel, Chicago, Ill. Raymond Olney, P.O. Box 229, St. Joseph, Mich. is secretary.



NEW AJAX DIHEDRAL COUPLING CAN BE LINED UP WITH YOUR EYE

Handles Misalignment Heretofore Considered Excessive

Introduction of the new Ajax Dihedral Coupling is saving thousands of hours and dollars all the way from machine design to actual installation and maintenance. The ability of Ajax Dihedral Couplings to handle misalignment heretofore considered excessive is based on the exclusive tooth shape which permits handling shaft misalignment far beyond the capacity of conventional flexible couplings.

Tooth clearance (backlash) in Ajax Dihedral Couplings is kept to oil film requirements.

Difficult misalignment problems are eliminated under conditions of settling foundations, old or inadequate wooden floors, weaving chassis or structural mountings.

Standard Dihedral Couplings are made to handle misalignment up to 7°. Teeth can be cut to handle greater misalignment but each job must be engineered.

Write for Bulletin 50.

AJAX KNOWS COUPLINGS

Working Hand-in-Hand With America's Leading Manufacturers and Users of Direct-Connected Machines for Thirty Years...

AJAX FLEXIBLE COUPLING CO. INC.

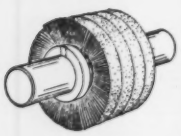
WESTFIELD, NEW YORK

How Can You Use Fullergript?

Here's What Others Are Doing

GRINDER SHROUD
devised from Fullergript brush strip by maker of vertical die and surface grinder . . . concentrates coolant and protects operator from spray.

REMOVING GLOSS
from molded counter top accomplished by buffing cylinder with widely-spaced but spiralled Fullergript brush strips. Engineering trick was to work out angle of spiral giving an even buff.



WATER DEPOSIT
flicked away automatically from tops of cans coming from cooling machine in cannery. Hand labor eliminated.

CREEPING PREVENTED
by printing press manufacturer who utilized Fullergript formed as 2″ discs, which hold paper against stop fingers.

NEW ANSWERS
to puzzling problems can often be found with the brushing action of Fullergript strips. You are introduced to new vistas of mechanical possibilities. And our engineers will work with you. Tell us how you can use it — we're good listeners.

FULLER BRUSH
FULLERGRIPT
At home... in business, too

THE FULLER BRUSH COMPANY
INDUSTRIAL DIV., 3647 MAIN ST., HARTFORD 2, CONN.

New Machines

Business Equipment

DUPLICATING MACHINE: Model D-270 features continuous all automatic inking system, hairline registration and positive paper feed, silk screen and oscillating ink rollers, quick changing of colors. Printing size: 8½ by 13½ in.; speed, up to 8000 impressions per hr. Powered by universal built-in a-c and d-c motor. *Rex-Rotary Distributing Corp., New York, N. Y.*

Domestic

REFRIGERATORS: Model DO-90P has porcelain-on-steel exterior and acid-resisting porcelain interior. Capacity, 9 cu ft; stores 46 lb frozen food. Features include Frigidaire Meter-Miser refrigerating unit, rust-proof aluminum shelves, adjustable sliding shelf, two Hydrators with 3/5-bushel capacity. Standard model SO-92 has 9.2 cu ft storage space and 17 sq ft shelf area, stores 29 lb frozen food. Has porcelain finished interior, meat storage drawer, two Hydrators, rust-resisting shelves, Meter-Miser. *Frigidaire Division, General Motors Corp., Dayton, O.*

Earthmoving

SHOVEL-MOUNTED TRACTORS: Standard bucket capacities up to 4 yd; light material buckets up to 7 yd now available. Model HD-9G mounts 2 yd bucket, dumps at maximum height of 11 ft 4½ in.; HD-15G, 3 yd bucket, 12 ft 8-in. dumping height; HD-20G, 4 yd bucket, 13 ft 5-in. dumping height. Special buckets available. *Allis-Chalmers Mfg. Co., Tractor Division, Milwaukee, Wis.*

Farm Equipment

TRACTOR: Two-three plow unit with 20 per cent more engine horsepower. Steel disk-type front wheels; front axle width adjustable without readjusting steering connections. Overall dimensions: 115 in. long, 64 in. wide, 52 in. high. Wheelbase, 70 in.; ground clearance, under center, 13 in.; weight, approximately 2580 lb. *Harry Ferguson Inc., Detroit, Mich.*

Heat Treating

PORTABLE ELECTRIC OVEN: Low-priced Model HT for processing for stress

MEMO

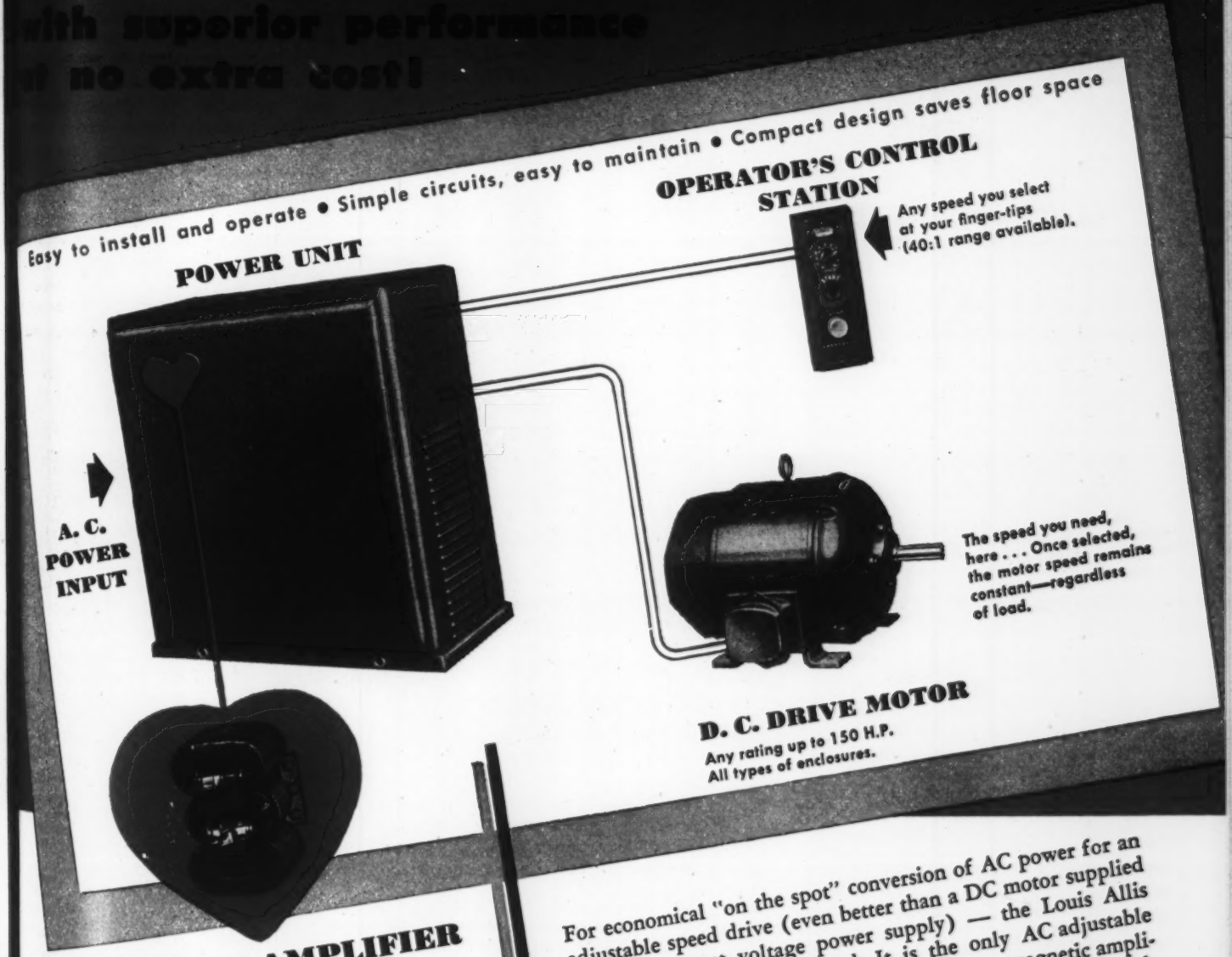
To: users of A.C. adjustable Speed Drives

from: THE LOUIS ALLIS CO.

only SELECT-A-SPEDE

offers the NEW MAGNETIC AMPLIFIER CONTROL with superior performance at no extra cost!

Easy to install and operate • Simple circuits, easy to maintain • Compact design saves floor space



THE MAGNETIC AMPLIFIER

- HEART OF THE SELECT-A-SPEDE

The Magnetic Amplifier, a self-saturating reactor, like a transformer, contains no moving parts — no parts requiring maintenance or periodic replacement. Its function in the Select-A-Spede, is to constantly regulate the field currents of both motor and generator. It requires no "warm up" period, has an extremely fast response to changing conditions, and is completely reliable at all times.

For economical "on the spot" conversion of AC power for an adjustable speed drive (even better than a DC motor supplied from a constant voltage power supply) — the Louis Allis Select-A-Spede is unsurpassed. It is the only AC adjustable speed drive offering the advantage of the new magnetic amplifier control — with close speed regulation at all rated speeds and loads.

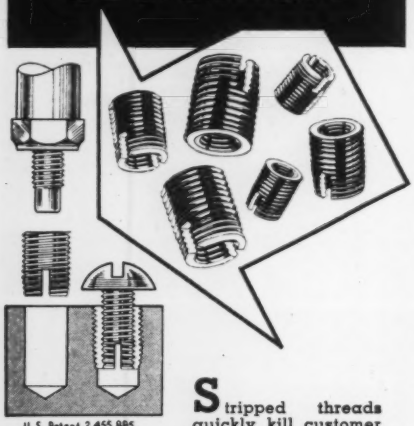
The Select-A-Spede also offers a variety of optional features, such as: reversing, dynamic braking, jogging, sequence control, controlled acceleration, interlocked slow speed start, multi-motor drives, etc. It is possible to provide a Select-A-Spede Drive to exactly suit your special requirements.

For further information, contact your nearest Louis Allis Application Engineer or write for Bulletin 1100-B.

LOUIS ALLIS

THE LOUIS ALLIS CO., MILWAUKEE 7, WIS.

TAP-LOK INSERTS save Man-hours and Customers



U. S. Patent 2,455,885

Stripped threads quickly kill customer goodwill. To prevent tapped thread failure in light metals, plastics, wood and similar materials, sound engineering calls for some form of hard bushing to increase the shear area. Among the various types available, TAP-LOK INSERTS have several important advantages:

(1) Self-tapping, they save many man-hours in assembly, in continuous production.
(2) They hold rigidly in position.
(3) Their cost is relatively low.

The TAP-LOK INSERT is quickly installed with a simple driving tool into a cored or drilled hole equal in size to a tap drill hole for the external thread of the Insert. It cuts its own thread, saving the cost of a separate tapping operation. It remains secure because the torque necessary to dislodge it is greater than the torque a standard machine screw can withstand. It suffers none of the uncertainties and losses in assembly that accompany the use of molded-in and cast-in inserts.

Send for samples and descriptive folder.

•

Also manufacturers of Groov-Pins—for positive locking press fit.

GROOV-PIN TRADE MARK REG. U.S. PAT. OFF.

GROOV-PIN CORPORATION

1129 HENDRICKS CAUSEWAY
RIDGEFIELD, NEW JERSEY

relief of springs and plated parts from 100 to 800 F. Features uniform temperature throughout. Can be used in groups or banks, or individually. Operates from 110-v outlet, 220-v units available. Thermostat, outside reading thermometer and pilot light are standard equipment. Size, 30 by 25 by 24 in. outside; 22 by 18 by 16 in. inside. *Grieve-Hendry Co. Inc., Chicago, Ill.*

Manufacturing

TUBE AND BAR STRAIGHTENER: Built in sizes for 5/16-in. to 20 in. OD tubes and 5/16-in. to 12 in. diameter bars. Model KTC employs seven straightening rolls. Group of three rolls at each end of machine composed of one large driven roll and two idler rolls disposed at an angle of approximately 120 degrees to each other. A middle idler roll deflects pipe. Roll arrangement eliminates use of guides and assures positive feeding. Middle roll manually adjusted, all others automatically adjusted to proper angularity for size of bar or tube being straightened. Speeds vary between 60 to 240 fpm using 200 hp, 300/1200 rpm adjustable-speed d-c motor. *Sutton Engineering Co., Bellefonte, Pa.*

METALLIZING GUNS: Metco Type 4E for machine element work and Type 5E for corrosion protection coatings, said to develop highest spraying speeds available in guns designed for hand-held operation. Provide nearly automatic operation, incorporating jet siphon principle in gas head which automatically compensates for variations in gas pressure up to 10 lb. Provides steady, unvarying flame which produces uniform coatings at low cost. Type 4E sprays all wires from 20 B&S gage to ⅛-in. in any metal; Type 5E sprays softer metals, such as zinc and aluminum. *Metallizing Engineering Co. Inc., Long Island City, N. Y.*

GAS CUTTING MACHINE: Airco No. 50 Travograph cuts variety of shapes from steel plates, slabs, billets and forgings. Rigid rail assembly provides smooth runway for carriage, guide rollers on base keep carriage on true, vibration-free course. Large diameter ball bearings in pantograph arm hinges and operating bar result in smooth, accurate response to movement of tracer. Self-contained carriage drive motor unit provides variations in carriage speed from 2 in. to 168 in. per min. *Air Reduction Sales Co., Division of Air Reduction Co. Inc., New York, N. Y.*

DRILLING AND TAPPING MACHINES: Heavy-duty model with self-contained power source includes two-cycle refrigerator type compressor, permits pressure adjustments from 0 to 500 lb. Drills up to 5/16-in. diameter in alloy steel or equivalent. Light-duty model employs shop air for power against 3 sq in. piston surface. Drills up to ¼-in. diameter in mild steel or equivalent. Both units features positive control drilling; are completely automatic. Size, 3¼ by 7⅝ by 18⅞ in. *Locke Gage Co., Detroit, Mich.*

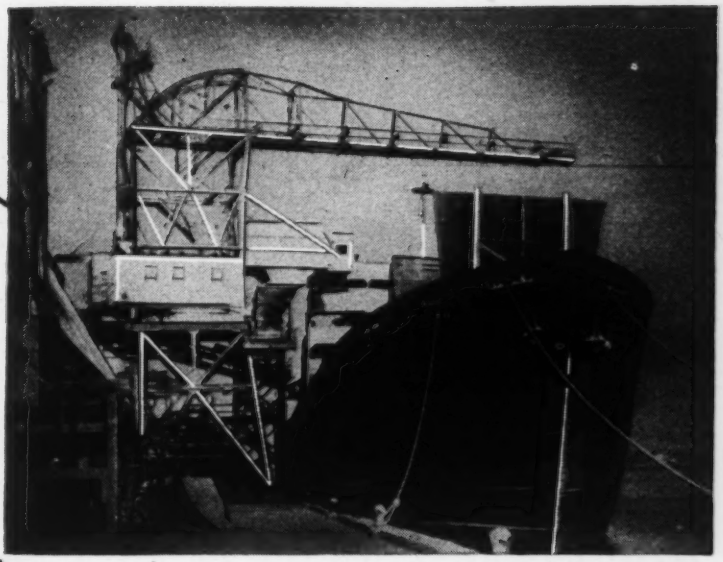
PRODUCTION PRESS: Capacity, 20 to 150 tons. Features include: flywheel type combination air-operated friction clutch and brake; pendent, pedestal or press-mounted clutch controls; four extra long gibs with eight guiding surfaces controlling slide in two directions; adjustable bronze ways on each corner of slide; long sleeve type manually-operated slide adjustment; four-piece tie rod construction. Has double-throw full eccentric shaft; variable-speed drives, having ranges to fit size and use of press. *Minster Machine Co., Minster, O.*

AUTOMATIC TRANSFER MACHINE: For drilling all oil passages and lightening holes in cast iron alloy crankshafts. Production capacity, 74 pieces per hour at 100 per cent efficiency. Crankshafts automatically positioned and hydraulically clamped prior to drilling at each station. High-speed tools revolve at 40 fpm with feed of 0.008-in. per revolution. Stroke of machine is 16 in. station to station. *Snyder Tool & Engineering Co., Detroit, Mich.*

STEAM-JET CLEANER: Operates at pressures up to 200 psi. Unit completely self-contained with space on all-steel truck to mount water tank of capacity for three to four hours of continuous operation. Speedy-lectric model JC-25 uses steam from built-in high pressure boiler; requires small quantities of solvents. Available for 220, 440 or 550-v; under ordinary conditions consumes 15-kw per hr. Size: 16 in. wide, 48 in. long. *Livingstone Engineering Co., Worcester, Mass.*

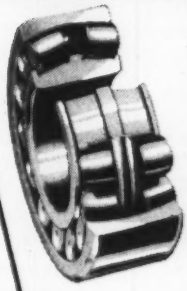
THREAD ROLLING MACHINE: Thommen type G-45 machine handles 120 to 1500 pieces per hour, depending on kind of metal and size of thread. Rolls threads of high precision with polished flanks and exact profiles in standard and special steels, most nonferrous metals, and light metals such as aluminum. Rolls threads with left or right-hand pitch, multiple pitch threads, threads within centers, very short

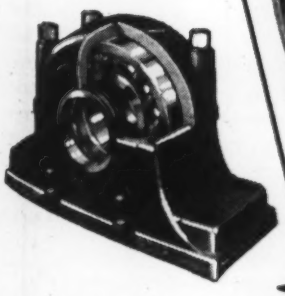
SHIP TO SHORE TO STORAGE



...600 GROSS TONS PER HOUR

The unloading tower and boom stacker, built by Derrick & Hoist Co., Inc., for a large New Jersey Plant, are just about the ultimate in modern, mechanized materials handling. The machines are a composite design of unloading tower and a revolving crane operating a large digging bucket, and a new type stacker with belt conveying and distributing equipment. The equipment handles 600 gross tons per hour . . . and heavy loads and brute punishment are "taken in stride" by SKF Pillow Blocks and Spherical Roller Bearings in the boom hoist and swinger, in the foot block of the stacker and in the conveyor drive.





Builders of all types of materials handling cranes for all industries rely on SKF. They recognize SKF dependability under all service conditions, SKF ability to supply the right bearing for the right place. 7259

8 REASONS WHY SKF IS PREFERRED BY ALL INDUSTRY

integrity
craftsmanship
metallurgy
tolerance control
surface finish
product uniformity
engineering service
field service

SKF

BALL AND ROLLER BEARINGS

* *For detailed information, write 24-16 Bridge Plaza, South, Long Island City 1, New York.*

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.
—manufacturers of SKF *and* HESS-BRIGHT *bearings.*

ARTIST • SOPHIE

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threads with collars and conical threads. Maximum pressure, 13,230 lb; thread diameters, from 5/64-in. to 1 57/64-in.; thread rolling pitch, from 0.016-in. to 5/32-in. Space required, 51 in. by 51 in. by 41½ in.; weight, 2646 lb. *Carl Hirschmann Co., Manhasset, N. Y.*

POWER PRESSES: Five deep-throat open back, inclinable units rated in 5 and 8 ton capacities. Will take work 20 in. and 24 in. in diameter, four shut heights from 6 in. to 13 in. with up to 3-in. strokes. *Famco Machine Co., Racine, Wis.*

ADJUSTABLE DRILL JIG: Used for drilling holes through round stock and hex stock from ¼ to 2 in., and for cap screws from ¼ to 1¼ in. Eliminates layout and cuts drilling time on small lots. Hardened V-block has two 60 deg V's for centering round or hexagonal stock, one for ¼-in. to 21/32-in. diameter, one for 21/32-in. to 2 in. diameter. Stop, adjustable up to 9 in., locates work longitudinally for drilling any distance from end on either side. Overall dimensions: 5¼-in. high; 4¼-in. wide, 7 in. long. *Mathewson Machine Works Inc., North Quincy, Mass.*

HYDRAULIC VISE: Fast-operating 4-in. jaw unit replaces previous 3½-in. model. Maximum hydraulic pressure, 7000 psi; maximum jaw pressure, 2 tons. Safety valve protects against overloading. Unit controlled by two foot pedals—one for power, the other for release. Closing speed of vise, ⅞-in. per pump stroke. *The Columbian Vise & Mfg. Co., Cleveland, O.*

HIGH PRECISION LATHE: Geared head engine Model DBC-175 with 13-in. swing. Available in high-speed model with range of 52 to 2000 rpm as well as standard model with range of 26 to 1000 rpm. Both machines have eight speeds and are powered by 3 hp motors. Features range of five longitudinal and five cross feeds without change of gear; removable gap providing maximum swing of 20¾-in. for a distance of 4½-in. in front of face plate. Has four-jaw chuck, built-in coolant system with electric pump, steady rest and standard tool post. *Kelvin Systems Corp., South Norwalk, Conn. and New York, N. Y.*

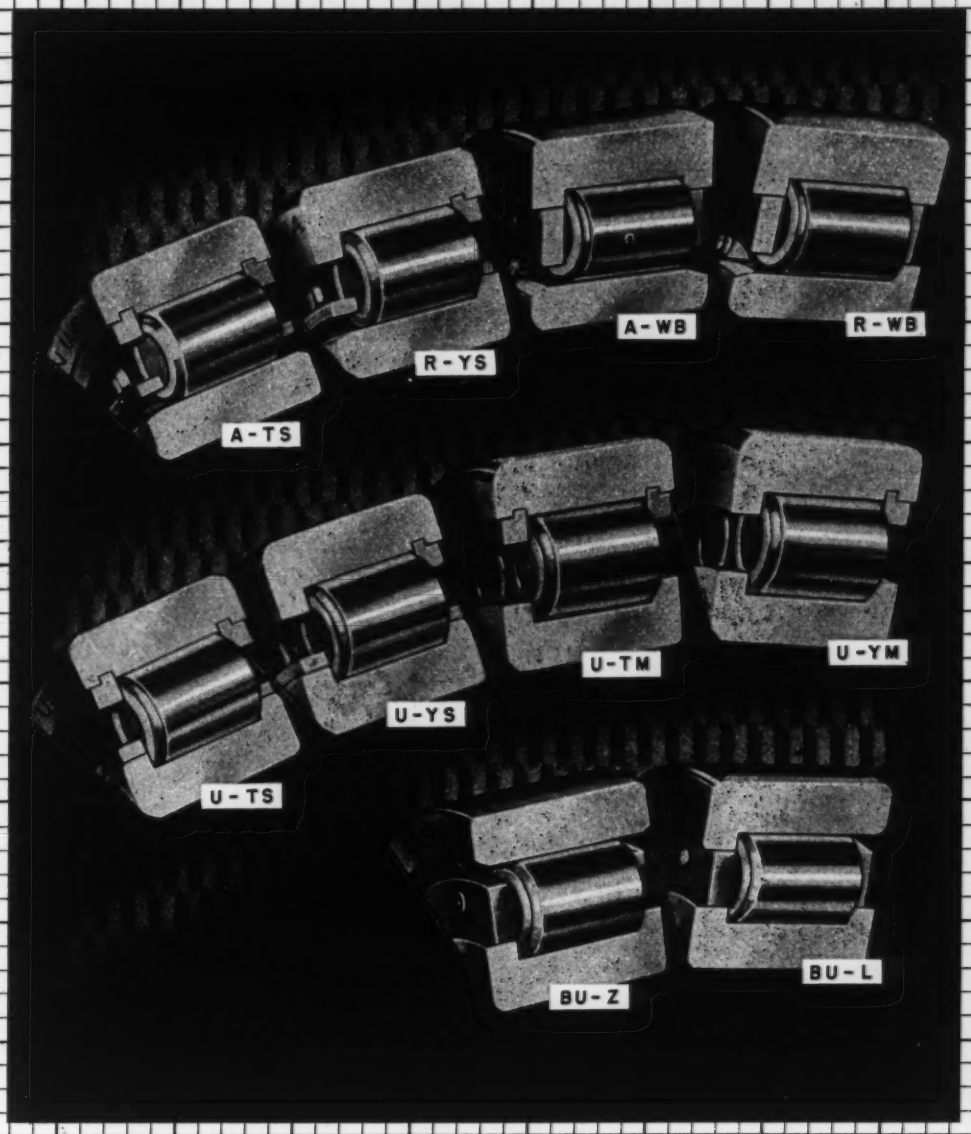
CIRCLE SHEAR AND FLANGER: High-speed unit shears and flanges a wide range of diameters and thicknesses of material without blanking, forming or drawing dies for the many different size heads. Cuts circular disks or arcs of sheet metal up to 8 gage mild steel or 12 gage stainless steel. Disks 8 in. to 58 in. in diameter cut from square blanks; up to 75½-in. diameter from octagonal blanks. Turns smooth, high flanges up to 1½-in. deep from circular disks. Upper roll is moved down by power with speed adjustable to suit diameter and thickness of blank. Heads require no further trimming or finishing for average commercial work. Head diameters from 18½ in. to 73½ in. can be flanged. *Niagara Machine & Tool Works, Buffalo, N. Y.*

TRANSFORMER WELDER: Model MCM 200 amp unit is designed for general maintenance and production welding. Has 50 per cent duty cycle, NEMA rating. Four variations available—220 v or 220/440/550-v units, each with or without power factor correction. Two open circuit voltages provided—80 volts on low range and 55 volts on high. Features insulation throughout, quick adjustment of welding current, no moving parts. *Air Reduction Sales Co., Division of Air Reduction Co. Inc., New York, N. Y.*

MULTIPLE SPINDLE DRILLING MACHINE: Three-spindle unit has ¾-in. capacity in steel, 1 in. in cast iron. Features 25-in. swing, variable-speed drive from which exact spindle speed may be obtained for any size drill from ⅛-in. to 1 in., and extra large table with coolant trough. Five spindle speeds, each with 4 to 1 ratio, are available, ranging from 206-825 rpm to 540-2160 rpm. Powered by 1½-hp 3-phase 60-cycle axial air-gap motor. Distance between spindles, 14⅞-in. Vertical adjustment of table, 12¼-in. Working surface of table, 45 in. by 14½ in. Weight with motors, 2165 lb. *Sibley Machine & Foundry Corp., South Bend, Ind.*

SCREW DRIVER-NUT SETTER: Air-powered Model 7500 has pushbutton control which provides instantaneous reverse action. Adjustable clutch can be preset to correct torque requirements. Clutch jaws automatically disengage when screw is set to desired tension. Speed, 1800 rpm; capacity, No. 0-8 machine screws. Can be quickly converted for nut-setting. Overall length, 7 11/16-in.; weight, 1.4 lb. *Aro Equipment Corp., Bryan, O.*

TRAVELING HEAD GRINDER: Grinds edges, angular surfaces, compounds and bevels, as well as machining pads on heavy castings 20 ft or longer. Series E-20 unit eliminates conventional traverse bed. Runs on self-powered precision rollers along rails machined to precision tolerances and equipped with built-in leveling devices. Employs 20-in. face-type grinding wheel mounted on head which tilts from horizontal to full vertical, has complete mobili-



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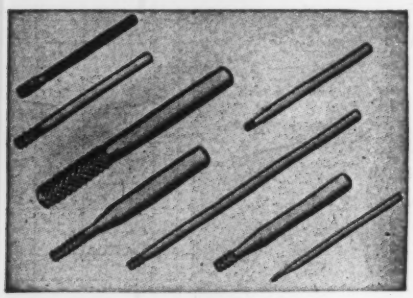

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ty with traverse rate continuously variable. Two or more grinders can operate simultaneously on one set of rails. Heavy-duty precision spindle assembly and 20-hp motor are mounted within rigid trunnions and arranged to feed in and out through 7-in. range, utilizing planetary gear driven motor reducer combined with precision lead screw. *Machine Tool Division, Mercury Engineering Corp., Milwaukee, Wis.*

DRILL GRINDER: For two-lip twist drills, from No. 70 to ¼-in. either straight or tapered shank. Offers economical, simple operation. Any included angle of drill point from 90 to 160 deg can be obtained, as well as any clearance angle from 5 to 15 deg. Powered by 1/5-hp 115-v Dumore motor, grinder swings 2-in. by ⅜-in. by ¼-in. wheel for sharpening. Identical wheel mounted on other end of armature shaft rough grinds broken drills to shape; thinner wheel for web thinning. Standard equipment includes 1¼-in. collet, chuck extension drill holder for No. 52-70 drills, diamond wheel dresser, set-up gage. *Dumore Co., Racine, Wis.*

HEAT SEALER: Portable air-operated aluminum unit with two heated 13-in. jaws. Designed especially to facilitate the heat-sealed wrapping of large objects such as aircraft engines, bulky electronic equipment, etc. Can also be used interchangeably for ordinary heat sealing of cellophane, pliofilm, polyethylene, saran, etc. Stand is available for use as stationary unit. *Globe Products-Heat Seal Corp., Los Angeles, Calif.*

RELIEF GRINDER: Speeds up grinding operations by as much as 300 per cent. Handles countersinks of all types, center drills, integral pilot cutters and right or left-hand pilot drills. Easily adjusted for correct relief and angle in relation to grinding wheel. Fits any standard grinder and handles work from 1/16 to 1 in. in diameter with standard collets. Lift of single cam variable from 0.001 to ⅛-in.; adjustment pins provided for 1, 2, 3, 4 and 6 fluted cutter grinding. *Western Aero Industries, Burbank, Calif.*

DIE CASTING MACHINE: Model IMP/96 features pilot-operated impact type injection cylinder with slide valve in head, controlled by finger-light trip lever; safety interlock valve prevents metal injection before dies are fully closed. Operates on standard 80 psi airline and consumes 0.55 cu ft free air per cycle of operation. Specifications include: size of dieplates, 9 in. by 6 in. by 1½ in.; die opening, 4 in.; toggle die locking pressure, 12 tons; casting capacity, 12 oz; maximum area of casting, 12 sq in.; space between tie-bars, 6¼-in.; floor space, 30 in. by 12 in.; weight, 450 lb. *DCMT Sales Corp., New York, N. Y.*

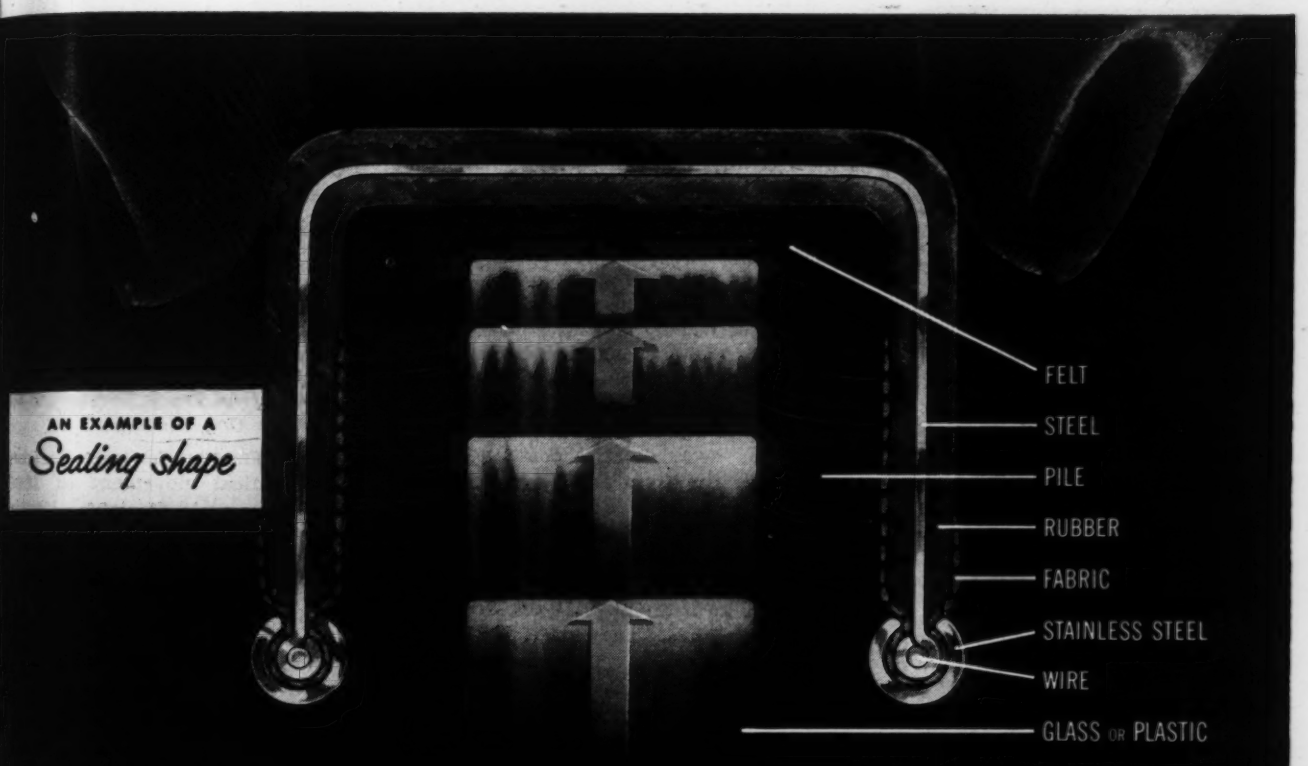
PRESS: For instrument and small parts production. Small, versatile unit for light-duty precision operation in staking, punching, piercing, reaming, broaching, marking, forming and riveting. Tools are guided by adjustable cross arm mounted on steel column. Standard adjustable fixture plate mounted on base contains 21 holes ranging from 0.013 to 0.185-in. diameter. Clearance between fixture plate and cross arm is adjustable to 1¼ in. *Metalix Manufacturing Co. Inc., East Norwalk, Conn.*

AIR SANDER: Straight-line unit speeds finishing of welded seams, produces smooth job, removes scratches, defects; leaves no swirls or pressure marks. Single-pad models for small areas; double-pad models for speedy work on large areas. Weights, from 5½ to 30 lb; speeds, from 1100 oscillations per minute on heavy duty unit to over 3000 on small model. *Sundstrand Machine Tool Co., Pneumatic Division, Rockford, Ill.*

TURRET LATHE: Available in two types—hand feed and power feed. Latter type available with screw feed or lever feed cross slide. Hand feed type available with lever feed cross slide. Automatic chuck capacity, 1 in.; swing-over cross slide, 6 in.; swing-over bed, 14 in. Belt-driven transmission provides positive, even power flow for smooth, accurate cutting, easy operation. Unit has six speeds forward and reverse. *G. M. Diehl Machine Works Inc., Wabash, Ind.*

WIRE ROLLING MILL: Model T-400 designed for flattening round and other types of wire. Roll size, 6 in. diameter by 4 in. face width. Two mill motors receive power from a single generator, operating from an a-c source. Motors synchronized by dancer roll rheostat. Water-cooled rolls run on full length roller bearings with separate thrust bearings. Floor space required, 5 by 15 ft. *Stanat Manufacturing Co., Long Island City, N. Y.*

WET BLAST MACHINE: Features vertical pump for slurry recirculation. Eliminates all suction piping, valves, fittings and labor for removing them for inspecting pump. Always primed by flooded-type suction; operation of valves for starting or stopping unnecessary. No loss of slurry through leakage. Hopper need not be drained before pump is removed. Rubber hose used



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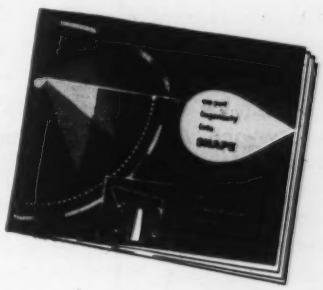

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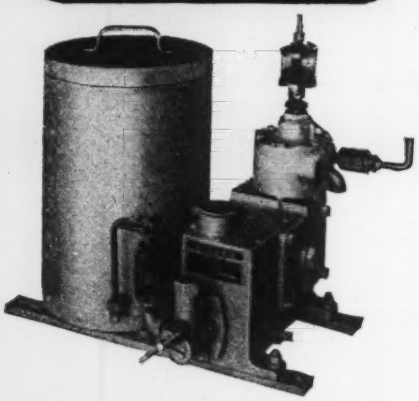

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GAST MANUFACTURING CORP., 107 Hinkley St., Benton Harbor, Mich.

instead of metal pipe wherever possible. Machine has low work ceiling. Reset timer available which tells number of blasting hours abrasive has been in machine. *American Wheelabrator & Equipment Corp., Mishawaka, Ind.*

TWIN COLUMN PUNCH PRESSES: Used for all types of blanking, forming, drawing and bending. Self-contained shearing attachment available for precision shearing. Design feature is pair of ram guides 4 in. in diameter, positioned vertically at exactly 90 degrees, reducing possible wearing to a minimum. Actuating mechanism of ram operates inside vertical ram posts. Guide sleeves move up and down on ram guides. Rapid action four-point clutch with sliding clutch dog provides smooth rapid action for high-speed production. Ram has two-inch adjustment. *Wales-Strippit Corp., North Tonawanda, N. Y.*

Materials Handling

FORK LIFT TRUCKS: Two pneumatic tire models in 2000 lb capacity, with 24 and 15 in. load centers. Features include: carriage mounted on adjustable side thrust rollers to eliminate wear; extra strength and self-aligning mast; single lever two-speed forward and two-speed reverse gear shift; quick change heavy-duty clutch. Powered with four-cylinder, 61 cu in. displacement engine. Available in five standard masts with lifts of 72, 84, 108, 114 and 120 in. *The Buda Co., Harvey, Ill.*

MECHANICAL FURNACE LOADER: Speeds loading and unloading operation by eliminating single piece handling. Work to be treated is placed on frame of loader, which handles several layers at once; entire load is picked up and inserted into furnace by fork bars of loader. Similarly, unloading is accomplished by inserting fork bars and withdrawing load from furnace. *A. D. Alpine Inc., Culver City, Calif.*

SHUTTLE CAR: Cable-reel crawler-type steel-track unit for mine application. Designed for operation in close quarters; has turning radius of from 14 to 16 ft. Provides for light ground-loading pressure by distributing weight over large ground area. Driven by two sealed-type 20-hp, 250-v series-wound motors driving each track through single gear reduction, chain and sprocket. *General Electric Co., Schenectady, N. Y.*

CARRIAGE ASSEMBLY: Special lift assembly makes 2000 to 4000 lb capacity fork truck a multipurpose handling machine. Functions as standard fork truck for pallet and ordinary fork truck handling, as clamp truck for handling drums, cartons, etc., and as fork-spacer for handling varying widths of pallets, skids or other loads. Simple change in adjustment converts it into side-shifting fork truck for carloading and storing operations. Hydraulic action, with roller conveyor chain linkage. Available in 36, 42, and 48 in. outside fork spread; provides 17 in. of fork-spacer and clamp action; as side shifter provides 4¼-in. lateral movement each side of center. *Baker Industrial Truck Division, Baker-Raulang Co., Cleveland, O.*

ELECTRIC TRUCK: For both horizontal and vertical movement of 1000-lb loads up to 48-in. long. Features telescopic design in models of 59, 71 and 83 in. collapsed height, providing 82, 106 and 130 in. fork elevation, respectively. Overall length, 46½ in. with forks in carrying position. All operating controls located in handle head. *Lewis-Shepard Products Inc., Watertown, Mass.*

Processing Equipment

PACKAGED DRYING UNIT: For drying of chemical products, raw materials, etc., and for drying expensive or delicate products. Has rotary dryer with drive, screw feeder, air heater, fan and dust collector integrally mounted on steel frame. Continuous feeding accomplished by means of special feeder directly to interior of dryer. Equipped with drive permitting variation of feed rate over 3 to 1 range. Preheated air provided by oil or gas fired air heater; steam may also be used. Furnished in 2, 2½ and 3 ft diameters and 10 to 24 ft lengths. *Patterson Foundry & Machine Co., East Liverpool, O.*

Power Plant Equipment

MOTOR GENERATOR SET: Mono-coil high-frequency unit used to convert 60-cycle current to 180 and 360-cycle frequencies. Self-exciting set has built-in voltage regulation which automatically compensates for fluctuations in voltage to load. Compact, easily-installed unit available in many ratings and speeds. *Electric Machinery Mfg. Co., Minneapolis, Minn.*

Woodworking Equipment

SANDER: Powered by heavy-duty Universal motor. Sands wood and metal. Abrasive pad revolves in ¼-in. diameter orbit at 4000 rpm. Sands with, against and across grain without scratch or mar. Size: 9½ in. long, 4⅛ in. wide, 6½ in. high; weight, 6 lb. *Porter-Cable Machine Co., Syracuse, N. Y.*

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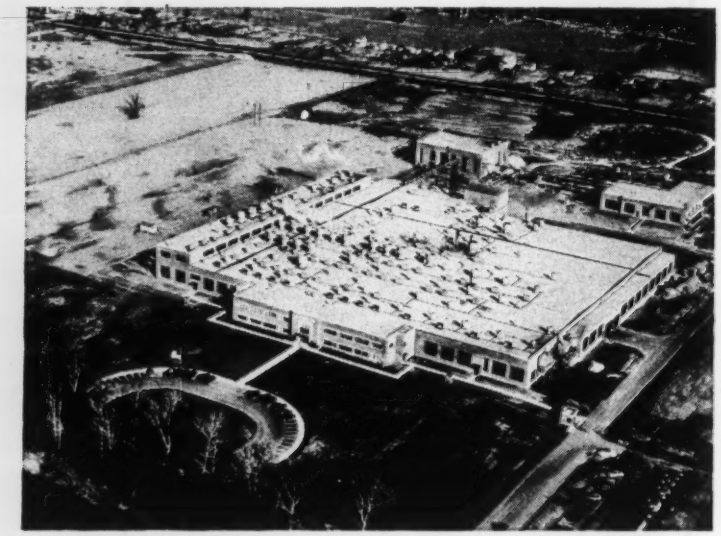

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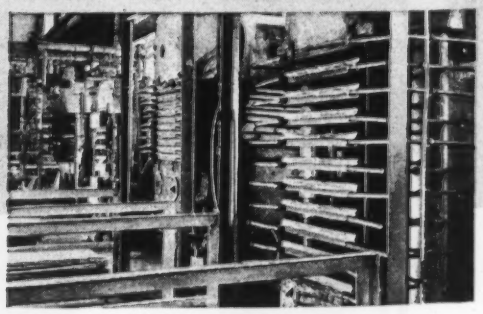

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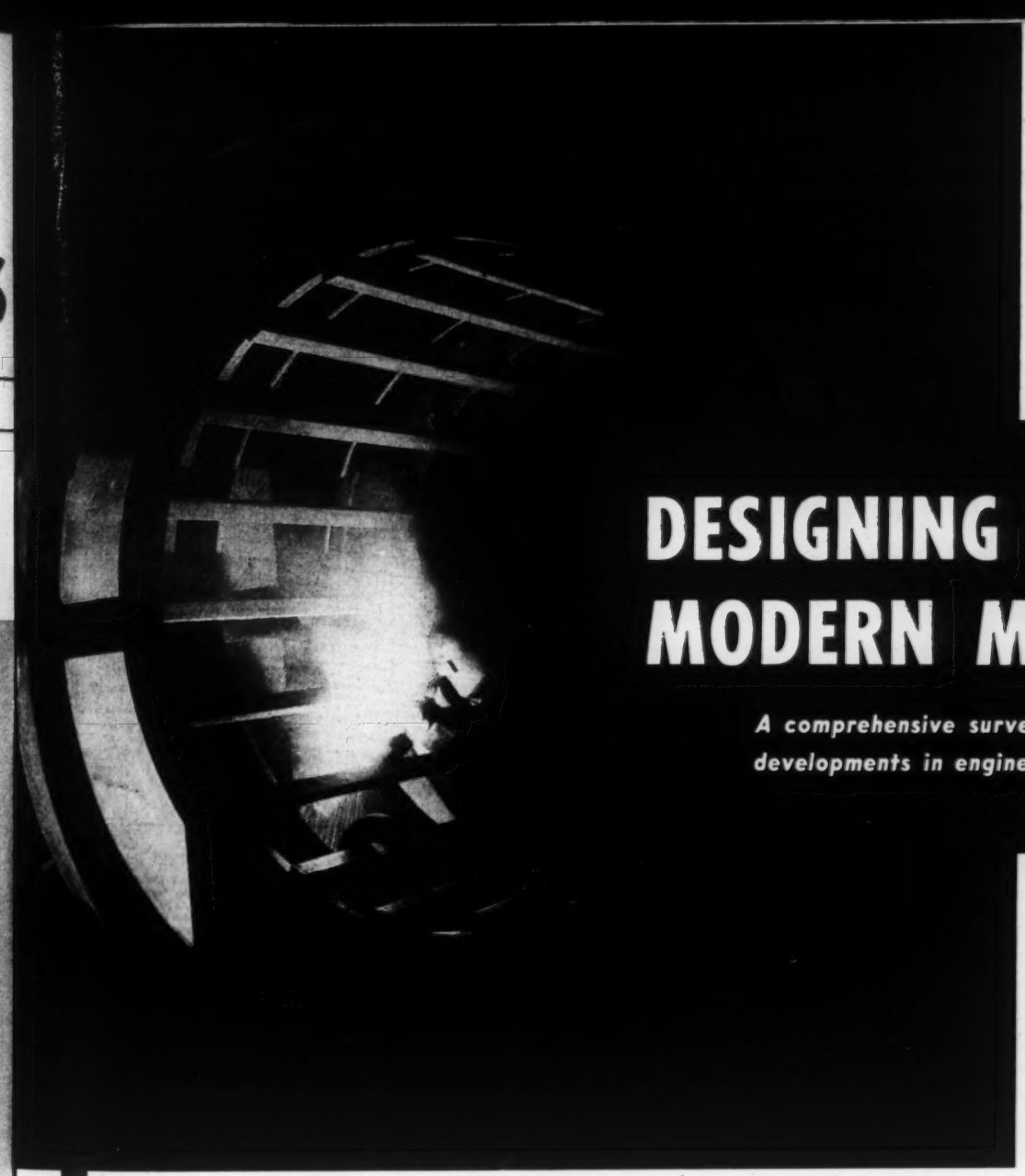


DESIGNING WITH MODERN MATERIALS

A comprehensive survey of the latest developments in engineering materials

IN THESE times of high production and emergency the everpresent problems of materials selection assume critical proportions. Although compatibility of cost and service cannot be ignored, conservation and availability often must take precedence. Materials must be at least satisfactory for the application. But of equal importance, they must be available and economical in terms of processability, cost, and depletion of critical supplies. To this end it behooves the designer to give serious thought and renewed attention to the overall problem.

In his study of materials adaptation with this goal in mind, the designer must need consider all recent developments in this field pertinent to machine design. To assist in making such a sweeping review, the Editors of MACHINE DESIGN have canvassed manufacturers over a period of months garnering details on up-to-the-minute engineering materials developments. Here, brought together in brief form, these data are compiled in basic groupings to serve as a design reference. Developments have been numerous; the possibilities of application almost limitless.

The need for analytical survey of the materials problem has been emphasized in numerous ways not the least of which has been that of substitution. Today, the easy out of substitution might almost be said to be nonexistent. Most ready substitutes of the past are today on a par with what have been termed "critical materials" from the standpoint of supply. The answer, therefore, lies in the direction of the material offering practical service life with

minimum amount and cost in terms of raw stock and processing. Most important, perhaps, is the increased service life offered by improved or new materials—size can be reduced, production often increased, weight eliminated.

To complete the compilation and round out its value as a reference, a listing of materials specifying agencies is included at the end of the article. Data on the agency, address and other pertinent information should prove of assistance in speeding specifications and meeting drawing requirements.

METALLICS

FERROUS

New and Modified Alloy Steels: Increasing scarcities of critical alloying elements and further restrictions in their use have resulted in a series of new alloy steels. These new steels are for the most part modifications of time-proved types. They are designed to perform the functions of their prototypes while conserving scarce alloying elements.

BORON-TREATED ALLOYS: One hears much today of "boron-treated" steels, "Tentative standard" (TS) steels, "modified steels." The following paragraphs attempt to explain these terms.

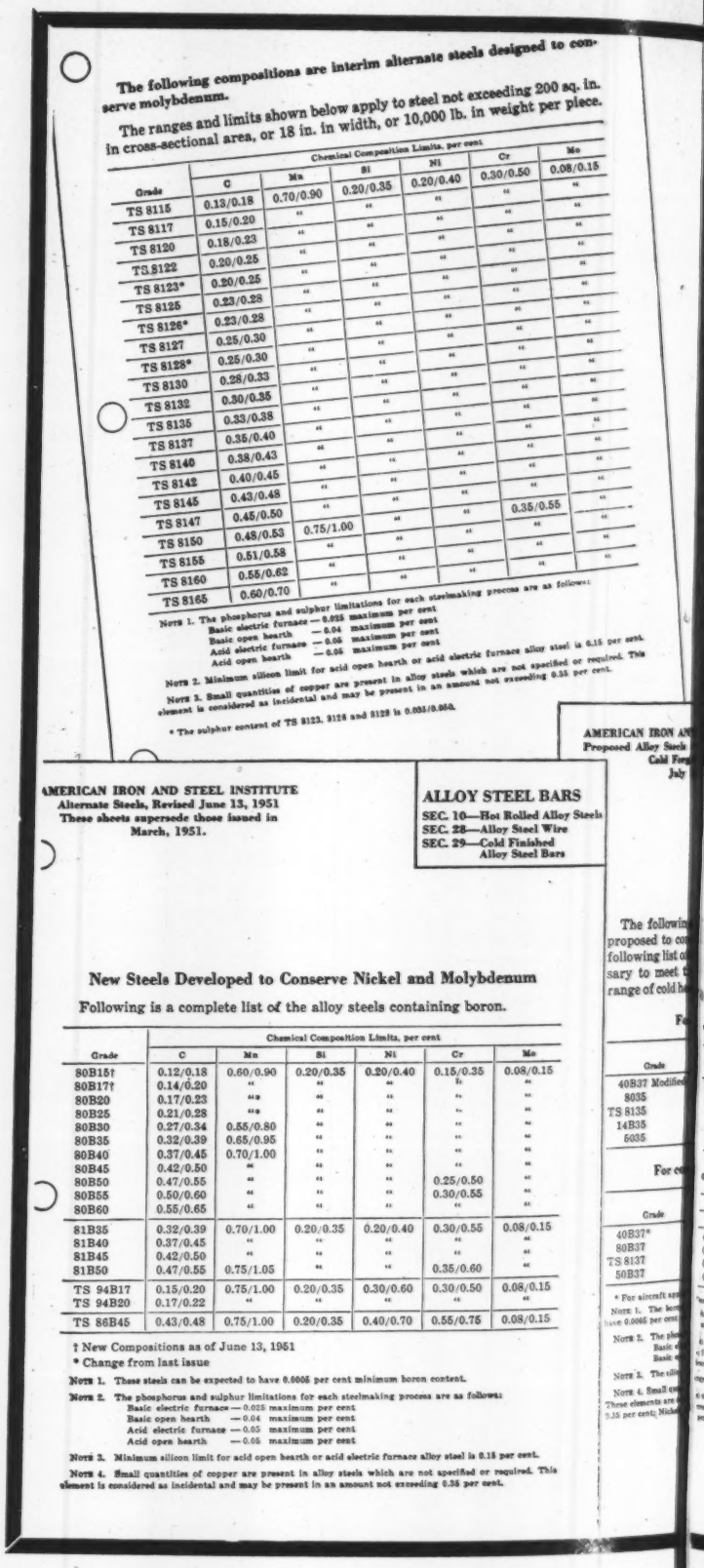
Boron is an element which, when added to steel under proper conditions, performs in one respect in the same manner as manganese, nickel, chromium, molybdenum, and vanadium. It imparts deeper hardenability to steel. Like the others, it is a "hardening agent."

The potency of boron is so great—even when added in minute quantities—that it permits a substantial reduction of the standard alloying elements. As an example, the addition of approximately 0.001 per cent boron to a steel of about 1.30 per cent nominal total nickel-chromium-molybdenum content will impart to it the hardenability characteristics of a similar untreated steel of about 2.80 per cent nominal total alloy content.

Boron as an alloying element is neither new nor untried. Its effects as a hardenability agent have been known for years. Limited quantities of boron-treated steels have been used commercially with considerable success for almost a decade. However, these applications have been limited in number, and were made only after extensive testing. The full range of boron-treated steels now becoming available are as yet largely untried under field service conditions. For this reason it is suggested parts made from boron-treated steels be thoroughly tested before going into commercial production.

The designation "tentative standard" (TS) has been given the modified former AISI 8600 steels, designed to conserve molybdenum, and the new 8100 series, interim alternate steels designed to conserve both nickel and molybdenum. Two boron-treated low nickel-chromium-molybdenum types (TS86B45, TS94B17, TS94B20) have also been designated tentative standard. The TS4100 series is designed to conserve nickel and molybdenum; TS4012 and TS4720 to conserve nickel.

A reduction of molybdenum content in the TS8600



The following compositions are interim alternate steels designed to conserve molybdenum.

The ranges and limits shown below apply to steel not exceeding 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece.

Grade	Chemical Composition Limits, per cent C	Mn	Si	Ni	Cr	Mo
TS 8115	0.13/0.18	0.70/0.90	0.20/0.35	0.20/0.40	0.30/0.50	0.08/0.15
TS 8117	0.15/0.20	"	"	"	"	"
TS 8120	0.18/0.23	"	"	"	"	"
TS 8122	0.20/0.25	"	"	"	"	"
TS 8123*	0.20/0.25	"	"	"	"	"
TS 8125	0.23/0.28	"	"	"	"	"
TS 8126*	0.23/0.28	"	"	"	"	"
TS 8127	0.25/0.30	"	"	"	"	"
TS 8128*	0.25/0.30	"	"	"	"	"
TS 8130	0.28/0.33	"	"	"	"	"
TS 8132	0.30/0.35	"	"	"	"	"
TS 8135	0.33/0.38	"	"	"	"	"
TS 8137	0.35/0.40	"	"	"	"	"
TS 8140	0.38/0.43	"	"	"	"	"
TS 8142	0.40/0.45	"	"	"	"	"
TS 8145	0.43/0.48	"	"	"	"	"
TS 8147	0.45/0.50	"	"	"	0.35/0.55	"
TS 8150	0.48/0.53	0.75/1.00	"	"	"	"
TS 8155	0.51/0.58	"	"	"	"	"
TS 8160	0.55/0.62	"	"	"	"	"
TS 8165	0.60/0.70	"	"	"	"	"

NOTE 1. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

NOTE 2. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

NOTE 3. Small quantities of copper are present in alloy steels which are not specified or required. This element is considered as incidental and may be present in an amount not exceeding 0.35 per cent.

* The sulphur content of TS 8123, 8126 and 8128 is 0.035/0.050.

AMERICAN IRON AND STEEL INSTITUTE
Alternate Steels, Revised June 13, 1951
These sheets supersede those issued in March, 1951.

ALLOY STEEL BARS
SEC. 10—Hot Rolled Alloy Steels
SEC. 28—Alloy Steel Wire
SEC. 29—Cold Finished Alloy Steel Bars

New Steels Developed to Conserve Nickel and Molybdenum

Following is a complete list of the alloy steels containing boron.

Grade	Chemical Composition Limits, per cent C	Mn	Si	Ni	Cr	Mo
80B15†	0.12/0.18	0.60/0.90	0.20/0.35	0.20/0.40	0.15/0.35	0.08/0.15
80B17†	0.14/0.20	"	"	"	"	"
80B20	0.17/0.23	"	"	"	"	"
80B25	0.21/0.28	"	"	"	"	"
80B30	0.27/0.34	0.55/0.80	"	"	"	"
80B35	0.32/0.39	0.65/0.95	"	"	"	"
80B40	0.37/0.45	0.70/1.00	"	"	"	"
80B45	0.42/0.50	"	"	"	"	"
80B50	0.47/0.55	"	"	"	0.25/0.50	"
80B55	0.50/0.60	"	"	"	0.30/0.55	"
80B60	0.55/0.65	"	"	"	"	"
81B35	0.32/0.39	0.70/1.00	0.20/0.35	0.20/0.40	0.30/0.55	0.08/0.15
81B40	0.37/0.45	"	"	"	"	"
81B45	0.42/0.50	"	"	"	"	"
81B50	0.47/0.55	0.75/1.05	"	"	0.35/0.60	"
TS 94B17	0.15/0.20	0.75/1.00	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
TS 94B20	0.17/0.22	"	"	"	"	"
TS 86B45	0.43/0.48	0.75/1.00	0.20/0.35	0.40/0.70	0.55/0.75	0.08/0.15

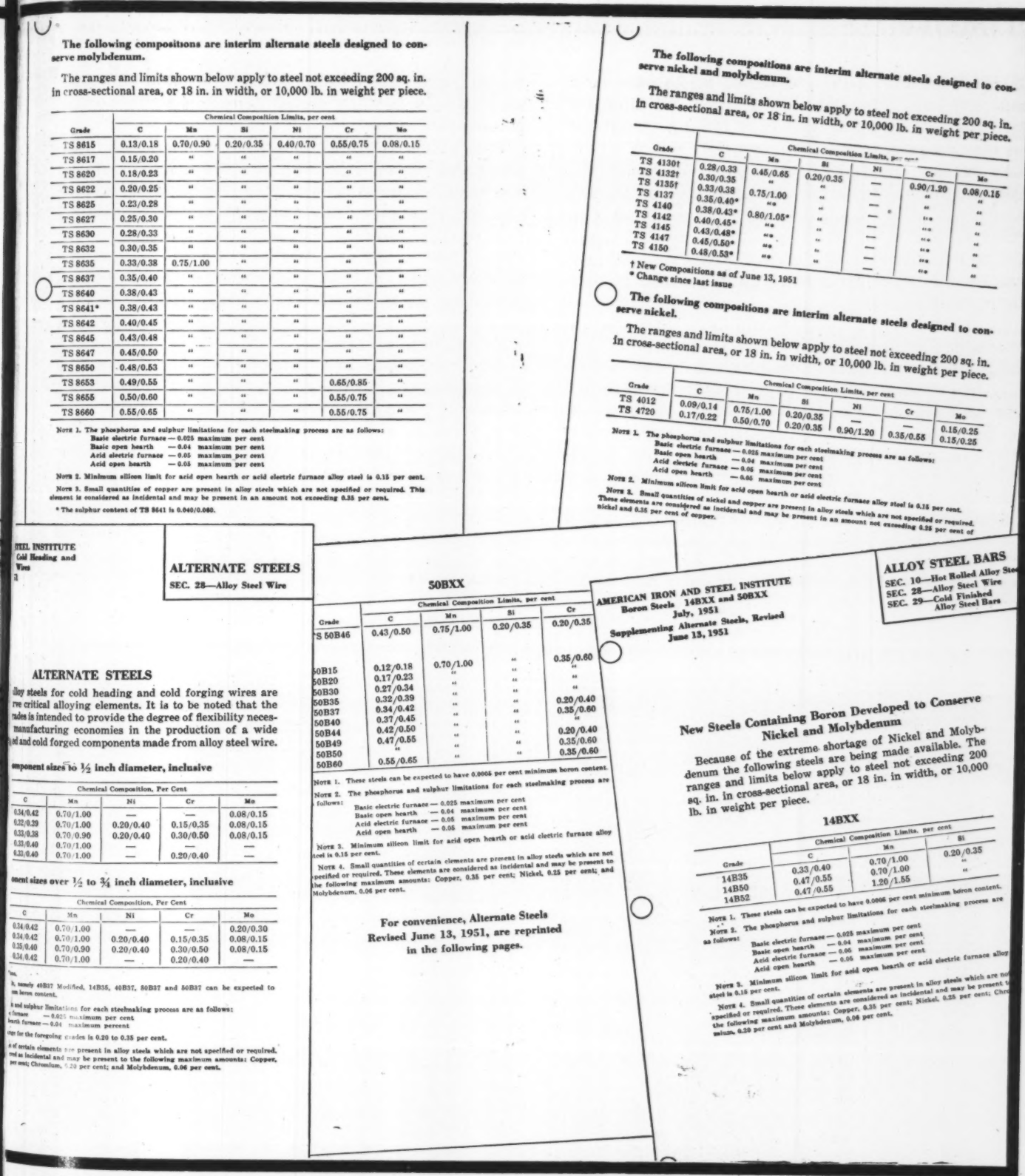
† New Compositions as of June 13, 1951
* Change from last issue

NOTE 1. These steels can be expected to have 0.0005 per cent minimum boron content.

NOTE 2. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

NOTE 3. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

NOTE 4. Small quantities of copper are present in alloy steels which are not specified or required. This element is considered as incidental and may be present in an amount not exceeding 0.35 per cent.



The following compositions are interim alternate steels designed to conserve molybdenum.

The ranges and limits shown below apply to steel not exceeding 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece.

Grade	Chemical Composition Limits, per cent					
	C	Mn	Si	Ni	Cr	Mo
TS 8615	0.13/0.18	0.70/0.90	0.20/0.35	0.40/0.70	0.55/0.75	0.08/0.15
TS 8617	0.15/0.20	"	"	"	"	"
TS 8620	0.18/0.23	"	"	"	"	"
TS 8622	0.20/0.25	"	"	"	"	"
TS 8625	0.23/0.28	"	"	"	"	"
TS 8627	0.25/0.30	"	"	"	"	"
TS 8630	0.28/0.33	"	"	"	"	"
TS 8632	0.30/0.35	"	"	"	"	"
TS 8635	0.33/0.38	0.75/1.00	"	"	"	"
TS 8637	0.35/0.40	"	"	"	"	"
TS 8640	0.38/0.43	"	"	"	"	"
TS 8641*	0.38/0.43	"	"	"	"	"
TS 8642	0.40/0.45	"	"	"	"	"
TS 8645	0.43/0.48	"	"	"	"	"
TS 8647	0.45/0.50	"	"	"	"	"
TS 8650	0.48/0.53	"	"	"	"	"
TS 8653	0.49/0.55	"	"	"	0.65/0.85	"
TS 8655	0.50/0.60	"	"	"	0.55/0.75	"
TS 8660	0.55/0.65	"	"	"	0.55/0.75	"

Note 1. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

Note 2. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

Note 3. Small quantities of copper are present in alloy steels which are not specified or required. This element is considered as incidental and may be present in an amount not exceeding 0.35 per cent.

* The sulphur content of TS 8641 is 0.040/0.060.

The following compositions are interim alternate steels designed to conserve nickel and molybdenum.

The ranges and limits shown below apply to steel not exceeding 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece.

Grade	Chemical Composition Limits, per cent					
	C	Mn	Si	Ni	Cr	Mo
TS 4130†	0.28/0.33	0.45/0.65	0.20/0.35	—	0.90/1.20	0.08/0.15
TS 4132†	0.30/0.35	"	"	—	"	"
TS 4135†	0.33/0.38	0.75/1.00	"	—	"	"
TS 4137	0.35/0.40*	"	"	—	"	"
TS 4140	0.38/0.43*	0.80/1.05*	"	—	"	"
TS 4142	0.40/0.45*	"	"	—	"	"
TS 4145	0.43/0.48*	"	"	—	"	"
TS 4147	0.45/0.50*	"	"	—	"	"
TS 4150	0.48/0.53*	"	"	—	"	"

† New Compositions as of June 13, 1951
* Change since last issue

The following compositions are interim alternate steels designed to conserve nickel.

The ranges and limits shown below apply to steel not exceeding 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece.

Grade	Chemical Composition Limits, per cent					
	C	Mn	Si	Ni	Cr	Mo
TS 4012	0.09/0.14	0.75/1.00	0.20/0.35	—	—	0.15/0.25
TS 4720	0.17/0.22	0.50/0.70	0.20/0.35	0.90/1.20	0.35/0.55	0.15/0.25

Note 1. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

Note 2. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

Note 3. Small quantities of nickel and copper are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present in an amount not exceeding 0.25 per cent of nickel and 0.35 per cent of copper.

STEEL INSTITUTE
Cold Heading and
Wire
1

ALTERNATE STEELS
SEC. 28—Alloy Steel Wire

ALTERNATE STEELS

lloy steels for cold heading and cold forging wires are rve critical alloying elements. It is to be noted that the rades is intended to provide the degree of flexibility neces- manufacturing economies in the production of a wide ed and cold forged components made from alloy steel wire.

omponent sizes to ½ inch diameter, inclusive

Chemical Composition, Per Cent				
C	Mn	Ni	Cr	Mo
0.34/0.42	0.70/1.00	—	—	0.08/0.15
0.32/0.39	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15
0.33/0.38	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15
0.33/0.40	0.70/1.00	—	—	—
0.33/0.40	0.70/1.00	—	0.20/0.40	—

onent sizes over ½ to ¾ inch diameter, inclusive

Chemical Composition, Per Cent				
C	Mn	Ni	Cr	Mo
0.34/0.42	0.70/1.00	—	—	0.20/0.30
0.34/0.42	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15
0.35/0.40	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15
0.34/0.42	0.70/1.00	—	0.20/0.40	—

ves.
s, namely 40B37 Modified, 14B35, 40B37, 50B37 and 50B37 can be expected to um boron content.
s and sulphur limitations for each steelmaking process are as follows:
c furnace — 0.025 maximum per cent
earth furnace — 0.04 maximum percent
ange for the foregoing grades is 0.20 to 0.35 per cent.
s of certain elements are present in alloy steels which are not specified or required. ered as incidental and may be present to the following maximum amounts: Copper, per cent; Chromium, 0.20 per cent; and Molybdenum, 0.06 per cent.

50BXX

Grade	Chemical Composition Limits, per cent			
	C	Mn	Si	Cr
TS 50B46	0.43/0.50	0.75/1.00	0.20/0.35	0.20/0.35
50B15	0.12/0.18	0.70/1.00	"	0.35/0.60
50B20	0.17/0.23	"	"	"
50B30	0.27/0.34	"	"	"
50B35	0.32/0.39	"	"	0.20/0.40
50B37	0.34/0.42	"	"	0.35/0.60
50B40	0.37/0.45	"	"	"
50B44	0.42/0.50	"	"	0.20/0.40
50B49	0.47/0.55	"	"	0.35/0.60
50B50	"	"	"	0.35/0.60
50B60	0.55/0.65	"	"	"

Note 1. These steels can be expected to have 0.0005 per cent minimum boron content.

Note 2. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

Note 3. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

Note 4. Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: Copper, 0.35 per cent; Nickel, 0.25 per cent; and Molybdenum, 0.06 per cent.

For convenience, Alternate Steels Revised June 13, 1951, are reprinted in the following pages.

AMERICAN IRON AND STEEL INSTITUTE
Boron Steels 14BXX and 50BXX
July, 1951
Supplementing Alternate Steels, Revised June 13, 1951

ALLOY STEEL BARS
SEC. 10—Hot Rolled Alloy Ste
SEC. 28—Alloy Steel Wire
SEC. 29—Cold Finished Alloy Steel Bars

New Steels Containing Boron Developed to Conserve Nickel and Molybdenum

Because of the extreme shortage of Nickel and Molybdenum the following steels are being made available. The ranges and limits below apply to steel not exceeding 200 sq. in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece.

14BXX

Grade	Chemical Composition Limits, per cent		
	C	Mn	Si
14B35	0.33/0.40	0.70/1.00	0.20/0.35
14B50	0.47/0.55	0.70/1.00	"
14B52	0.47/0.55	1.20/1.55	"

Note 1. These steels can be expected to have 0.0005 per cent minimum boron content.

Note 2. The phosphorus and sulphur limitations for each steelmaking process are as follows:
Basic electric furnace — 0.025 maximum per cent
Basic open hearth — 0.04 maximum per cent
Acid electric furnace — 0.05 maximum per cent
Acid open hearth — 0.05 maximum per cent

Note 3. Minimum silicon limit for acid open hearth or acid electric furnace alloy steel is 0.15 per cent.

Note 4. Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: Copper, 0.35 per cent; Nickel, 0.25 per cent; Chromium, 0.20 per cent and Molybdenum, 0.06 per cent.

Fig. 1—Tables showing latest AISI releases on new and alternate steels

series has been compensated by an increase in chromium. For practical purposes, hardenability remains approximately the same. These steels are designed as substitutes for the 8600 steels and can serve as alternates for the 8700 and 4100 groups. Full utilization of limited amounts of critical elements is achieved in the 80B00 and TS8100 series. The 80B00 series is designed to have hardenability equivalent to the old standard 8600 steels and the 81B00 equivalent to the old standard 4100 steels. TS94B17 is designed to have hardenability equivalent to the old 4820. All these steels may be specified boron treated for added hardenability.

To conserve both nickel and molybdenum type

TS50B46 and the 14B00 and 50B00 series have been made available. In addition, a group of alternate steels for cold heading and cold forging operations has been proposed.

As far as the design engineer is concerned, the processing and fabricating characteristics of the untreated new steels are little different from those with which he has been accustomed to working. In general, welding, machining, forging, annealing, and heat treating require either no change in practice or only slight modifications.

No particular difficulty should be experienced in processing boron-treated steels of 0.30 per cent carbon content and higher. Boron-treated steels must be fully quenched and tempered to obtain the effectiveness of boron. These steels offer no advantage in the normalized or annealed condition. Effectiveness of carbon diminishes as carbon increases and at approximately 0.90 per cent carbon no further effect on hardenability is noted.

Some difficulties have been reported in carburizing the low-alloy boron-treated types. While the core hardenability of a steel such as 80B20 may be adequate for a specified part, some difficulty may be experienced in case hardenability. Here again, carburizing and heat treating facilities as well as actual parts should be fully tested before going into commercial production.

It is well to keep in mind that any new grade recommended as a specific alternate for a former standard steel is offered primarily on the basis of hardenability. Past experience indicates that hardenability is a reliable yardstick for expected mechanical properties. Thus it may be said that if a machine part can be fully quenched and then tempered to 300 Brinell hardness, whether made from AISI 4140 or TS8640, or 80B40, the resulting mechanical properties will be substantially the same.

Steel producers are co-operating in an extensive program of testing the new steels, most of which are shown in the AISI tables of *Fig.* 1. While much information is already compiled, complete authoritative data are not yet available. Information is being passed on to metallurgists in manufacturing and fabricating plants as rapidly as possible.

Boron-treated steels offer American industry an opportunity to continue producing quality materials during the present emergency. As with any new product, a certain amount of testing and experimentation must be undertaken. The question as to whether

UNDERGOING HEAT TREATMENT here are axle shafts for the "Cat" No. 12 Motor Grader. Boron steel replaces 3½ per cent nickel steel (SAE 2345) and two per cent nickel-chromium-molybdenum steel (SAE 4340) for heavy-duty axle shafts at 3½ to 5½ inches in diameter, for motor graders and wheel tractors. No field failures of parts made from boron treated steels due to the use of this alloying element is the report from Caterpillar Tractor Co.

Beginning in 1939, Caterpillar was one of the first to use boron steel in mill heat lots. Experience covers more than 50,000 tons of the metal. During World War II, specifications for boron-treated steels were developed by the steel industry and applied to large quantities of armor plate and antitank projectiles. Behind this development were Army Ordnance, the American Iron & Steel Institute, and the Society of Automotive Engineers. Today, many manufacturers are considering a return to these steels for reasons of conservation. Only 0.002 per cent boron can cut the nickel-chromium-molybdenum requirements as much as one-half!

Without interruption, Caterpillar has continued to specify boron steel for such parts as heavy-duty axle shafts, cold-headed bolts and capscrews, and stud stock heat treated in cold-finished bar form. Quality controls are maintained by use of the SAE hardenability test and spectrographic analysis. Irregularities of the earlier boron treating of a mill heat are avoided by Caterpillar's method of testing the extremes before applying it in production.

TABLE 1—COMPARISON OF TITANIUM-BORON STEELS WITH WROUGHT HEAT-RESISTING STEELS

Steels (Nominal composition)	Stress (psi to produce rupture in 1000 hr at temperature indicated)			
	1000 F	1100 F	1200 F	1300 F
Standard Grades				
Killed Low-C Steel	13,000	.....	.....	.....
5 Cr, ½ Mo	19,000	11,000	6,000	3,300
7 Cr, ½ Mo	.....	14,000	6,500	3,400
9 Cr, 1 Mo	.....	18,000	8,300	3,800
27 Cr, type 446	.....	6,000	4,000	2,800
18-8, type 304	.....	28,000	15,000	9,000
18-8 Cb, type 347	.....	30,000	17,000	11,200
18-8 Mo, type 316	.....	33,000	25,000	17,000
24-12, type 309	.....	.....	20,500	11,700
25-20, type 310	32,000	24,000	17,000	11,000
16 Cr, 13 Ni, 3 Mo	.....	.....	26,000	17,000
Titanium-Boron Grades				
Low C, Ti-B	51,000	20,000	.....	.....
2.8 Cr, Ti-B	60,000	30,000	.....	.....
2.2 Cr, 0.5 Mo, Ti-B	65,000	40,000	.....	.....
2.2 Cr, 1.0 Mo, Ti-B	63,000	52,000	20,000	.....
6 Cr, Ti-B	.....	33,000	18,500	.....
12 Cr, Ti-B	.....	19,000	.....	.....
12 Cr, 4 Ni, Ti-B	.....	15,000	.....	.....
18-10, Ti-B	.....	40,000	28,000	20,000

or not a certain job can be done can best be answered in your own plant.

In any period of change such as the present, it is only natural that problems arise and questions are posed. Until the new steels are thoroughly documented, the design and process engineer is urged to consult with a metallurgist, either his own or a steel producer's, for answers to specific questions.

Heat and Corrosion-Resistant Steels: Demand for good heat and corrosion-resistant materials has gained pace during the last several years. As a result, numerous developments have been made and cover a wide variety of types. Some developments portend important new design advances and indicate that materials possibilities are far from limited. To the contrary, these new variations show that continued research and ingenuity will result in many materials much more closely suited for both design and production requirements.

TITANIUM-BORON STEELS: In search for a simple, inexpensive agent to prevent grain coarsening of low-carbon titanium steels at normalizing temperatures over 1625 F, the Titanium Alloy Mfg. Div. of National Lead Co. sought to use up to 0.1 per cent boron. Although unsuccessful for this purpose, it was found that these steels containing over 0.007 per cent boron were not hot-short. Also, those having over 0.01 per cent boron can be hardened appreciably by quenching or even air cooling from 2100 F and retain an exceptional degree of hardness after tempering. As a consequence, these steels have been undergoing considerable laboratory testing to determine their suitability for high-temperature service.

Test results to date indicate very favorable properties. Some of these can be generally summed up as follows:

1. Ferritic steels containing up to at least 0.03 per cent boron can be hot rolled or forged successfully (1850 to 2000 F) if they contain also more than enough titanium to combine with all the carbon
2. Ferritic low-carbon steels containing at least six times as much titanium as carbon and 0.01 to 0.03 per cent boron can be hardened to over 80 Rockwell B by quenching or air-cooling from 2000 F or above
3. Tempering at 1000 to 1200 F after hardening as in (2), gives a slight increase in hardness, and softening is generally not serious until 1200 F is exceeded
4. In the hardened and tempered condition as specified in (2) and (3) the room-temperature strength is about doubled, with only an unimportant decrease in ductility, but considerably lower notch toughness unless the hardness is definitely below the maximum possible for the steel in question
5. The rupture strength of these titanium-boron steels, quenched or air-cooled from about 2100 F and tempered at 1000 to 1200 F, under sustained loading at 1000 or 1100 F, is greatly superior to that of other ferritic steels under the same conditions, and is comparable to that of austenitic steels
6. If the heat treatment is such as to give somewhat lower hardness and high-temperature rupture strength than the maximum attainable for the titanium-boron steel in question, notch toughness represented by about 15 ft-lb Izod or more may be provided, together with rupture strength much superior to that of other ferritic steels such as those containing molybdenum
7. These low-carbon titanium-boron steels are not subject to graphitization in 5000 hours at 1100 F even though fully killed with aluminum
8. The method of improving the high-temperature rupture strength of ferritic steels by adding 0.01 to 0.03 per cent boron and over 6 times as much titanium as carbon, hardening by air-cooling or

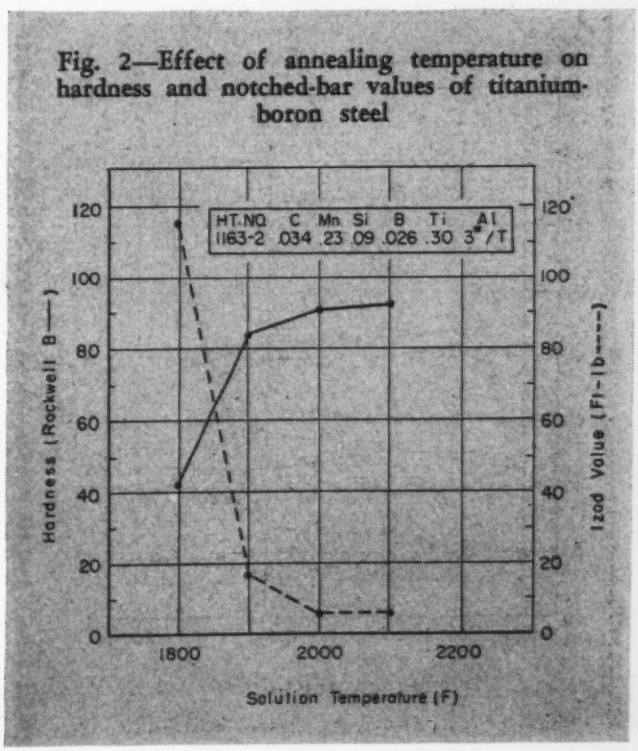


Fig. 2—Effect of annealing temperature on hardness and notched-bar values of titanium-boron steel

TABLE 2—MECHANICAL PROPERTIES OF HY-TUF AS HEAT TREATED*

Tempering Temp. (F)	Tensile Strength (psi)	Yield Str. (0.2% offset, psi)	Elong. (in 2 in., %)	Red. of Area (%)	Hardness (Rockwell C)	Impact Strength (Izod, ft-lb) 70 F	−40 F
400	239,000	183,000	14.3	46.6	48	33	29
500	235,000	191,000	13.9	49.7	47	33	27
550	234,000	193,000	13.1	49.7	46.5	31	25
600	230,000	194,000	14.0	51.7	46	29	26
700	222,000	193,000	14.2	53.3	45	24	23
750	210,000	190,000	14.6	53.6	44.5	21	21
800	201,000	180,000	13.6	50.6	43	23	20
900	181,000	162,000	16.3	54.4	39.5	36	18
1050	158,000	142,000	18.0	56.5	36	51	33

* Samples, one inch round, hardened at 1600 F, oil quenched and tempered as indicated, produced the tabulated mechanical properties.

quenching from above 2000 F, and tempering at 1000 to 1200 F, is applicable to oxidation-resistant steels containing 2 to 6 per cent chromium

9. The method specified in (8) is also applicable to the improvement of the rupture strength at 1100 or 1200 F of molybdenum and high-alloy steels.

The high hardness of titanium-boron steel is developed by a solution annealing treatment at a temperature of approximately 2000 F or above, followed by air cooling or water quenching for sizes up to one-inch diameter. The critical cooling rate required for larger sizes has not been established. *Fig.* 2 shows the effect of annealing temperature on the hardness and Izod notched-bar properties. From this chart, it can be seen that an annealing temperature of 1800 F yields a hardness of only 42 Rockwell B; a temperature of 2000 F gives a hardness of 91 Rockwell B.

The notch sensitivity of the steel is dependent, in a like manner, on the solution annealing temperature. If this temperature is too low to develop the high hardness, the Izod value is above 100 ft-lb. At a rather critical temperature the hardness is high and the Izod value drops considerably. For the particular case shown in *Fig.* 2 the critical annealing temperature is approximately 1900 F.

It has been established that the annealing temperature must be high enough to yield high hardness values in order to develop the outstanding high-temperature strength of the titanium-boron steel. The high-temperature strength and the Izod notched-bar values are interdependent also. In fact, the Izod value is a much more sensitive indicator of proper heat treatment than the hardness value.

Fig. 3 shows the influence of tempering temperature on the hardness and Izod values of specimens annealed at 1900, 2000, and 2100 F for ½-hour periods, followed by air cooling. Annealing temperatures of 2200 and 2300 F were investigated, but these high temperatures yielded no advantages and were detrimental as far as scaling was concerned. The specimens were approximately ⅝-inch square. Tempering at 1000, 1100, 1200, and 1300 F was for one hour, in each case, followed by air cooling.

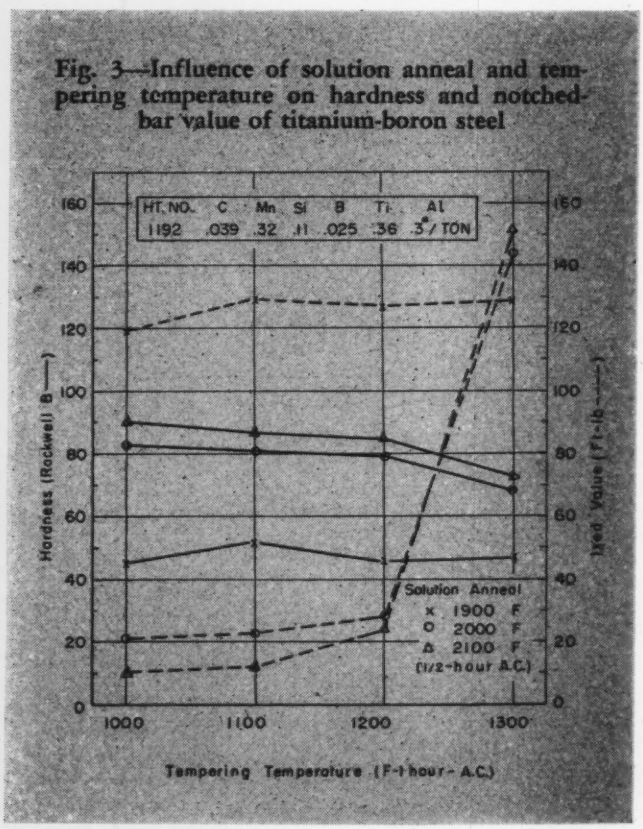


Fig. 3—Influence of solution anneal and tempering temperature on hardness and notched-bar value of titanium-boron steel

TABLE 3—COMPARISON OF HY-TUF WITH STANDARD STEELS

(Hardness of 475 Brinell)

Grade	Temper (F)	Tensile Str. (psi)	Yield Point (psi)	Elongation (% in 2 in.)	Red. of Area (%)	Izod Impact (ft-lb)
Hy-Tuf	400	239,000	183,000	14	47	33
8645	600	235,000	210,000	11	40	12
3145	500	245,000	218,000	8	28	5
3250	600	243,000	214,000	9	37	8
2345	575	240,000	220,000	13	40	9
4640	550	238,000	218,000	11	43	14
4340	690	242,000	222,000	12	45	14

It will be noted in *Fig.* 3 that the critical solution annealing temperature is between 1900 and 2000 F, since the hardness values are in the range of 45 to 52 Rockwell B and the Izod values are in the range of 119-129 ft-lb after the 1900 F anneal. After the 2000 F anneal, however, the hardness is 83 Rockwell B; the Izod, 21 ft-lb for the 1000 F temper.

Tempering at temperatures up to 1200 F produces little change in the hardness. At 1300 F the hardness decreases somewhat as the result of overaging. However, the Izod values change most markedly under these conditions. Solution temperatures of 2000 and 2100 F, followed by a 1200 F temper, yield Izod values of 19 to 28 ft-lb, and these increase to 144 to 158 ft-lb for the 1300 F treatment.

Stress values that produce rupture in 1000 hours at temperatures of 1000, 1100, 1200, and 1300 F for

TABLE 4--CHARACTERISTICS OF NO. 10 STAINLESS

Forms	Corrosion Resistance	Physical Constants	Workability	Treatment	Mechanical Properties
Forging billets Hot rolled bars and forgings Cold drawn and ground bars Wire and wire rods	Organic, inorganic, chemicals & foodstuffs ..... good Nitric acid ..... good Sulphuric acid ...fair Hydrochloric & halogen acids..poor	**Density** lbs per cubic inch. 0.29 **Melting point range** ..... 2550/2650 F **Specific Heat Btu.** per lb per deg. F (32-212 F) ..... 0.12 **Thermal Conductivity** Btu per hr per sq ft per ft per deg. F 212 F ..... 9.4 932 F ..... 12.4 **Specific electrical resistance** at 68 F. Ohms per cir mil ft..... 416 **Coefficient of Thermal Expansion** mean 32 to 1200 F.... ..... 10.4×10^{-6} **Modulus of Elasticity** in tension psi .... 28.0×10^{-6}	**Coldworking:** Excellent for blanking, forming, swaging, upsetting, and heading. **Hotworking:** Can be forged, hot-headed, upset and riveted satisfactorily. **Scaling:** Safe scaling temperature in continuous service of 1600 F. **Machinability:** Machines with tough, stringy chip and chip curlers and breakers are helpful. Machinability can be improved by cold drawing. Speeds of 40-85 surface feet per minute should be used in turning operations. **Welding:** Can be welded, brazed, and soldered satisfactorily.	**Forging:** Heat uniformly to 2100-2250 F. Do not forge below 1700 F. Forgings can be air cooled but better corrosion resistance is obtained if small forgings are water quenched from hammer and larger pieces are heated to at least 1900 F and water quenched. **Annealing:** Heat to 1900-2100 F, and quench in water. Brinell hardness approximately 153. **Hardening:** Cannot be hardened by heat treatment. Hardens very slowly by cold work.	(Typical tensile test at room temperature on 1 in. round after water quenching from 2000 F.) Yield strength (0.2% offset psi) ..... 35,000 Tensile strength (psi) ..... 75,000 Elongation in 2 in. (%).... 55.0 Reduction of area (%)..... 72.0 Hardness (Brinell) ..... 145 Hardness (Rockwell B)..... 80 Carpenter Stainless No. 10 cold heading wire is generally supplied at a slightly higher hardness than that shown above for this material in the fully annealed condition. This added hardness will assist in the fabrication of headed parts. Mechanical properties of No. 10 *at elevated temperatures* are about the same as for No. 4 (type 302) and No. 8 (type 303).

ten wrought, high-alloy, heat-resisting steels, killed low-carbon steel, and the eight titanium-boron steel compositions investigated by Titanium Alloy Mfg. Div. laboratory are given in TABLE 1. From this compilation it is evident that all four Ti-B grades tested at 1000 F are remarkably superior to standard grades, including the highly alloyed 25 per cent Cr, 20 per cent Ni steel.

At 1100 F, the plain Ti-B steel exhibits a higher stress to rupture for 1000 hours than all the ferritic standard steel types of chromium and chromium plus molybdenum. The 2.8 per cent Cr Ti-B and 6 per cent Cr Ti-B steels are comparable with the standard austenitic grades at 1100 F, while the 2.5 per cent Cr Ti-B steels with 0.5 per cent or 1.0 per cent Mo and the 18-10 Ti-B steel are appreciably superior.

The 1000 hour rupture values of only three grades of titanium-boron steel have been established at 1200 F. The 2.5 per cent Cr, 1.0 per cent Mo Ti-B and the 6 per cent Cr Ti-B steels are outstanding in comparison with the regular Cr-Mo ferritic steels, and are equivalent to the austenitic grades. The 18-10 Ti-B steel is superior to all the regular steels, including type 310, the best of the group.

At 1300 F only the austenitic Ti-B steel has been investigated, as it was felt that the other grades did not contain a sufficiently high chromium content for oxidation resistance at this temperature. The 18-10 Ti-B steel is superior to the best of the conventional steels at 1300 F.

HIGH-STRENGTH, HIGH-TOUGHNESS STEELS: Demand for strength levels in aircraft steels to match those of 70,000 psi aluminum alloy on a weight basis resulted in development of several new grades. To obtain equal efficiency, useful strength of over 210,000 psi with ductility and impact resistance equivalent to 4340 at the 180,000 psi heat-treated level were necessary. Among these recent developments are Republic's Cr-Ni-Mo-V, U. S. Steel's B-514, and Crucible's Hy-Tuf.

Typical of these steels, the composition of Hy-Tuf is generally as follows:

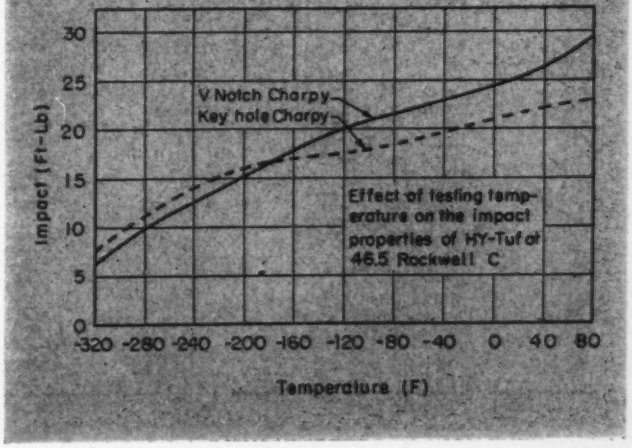
Carbon	0.25%
Manganese	1.30%
Silicon	1.50%
Nickel	1.80%
Molybdenum	0.40%

This steel is forged at 2000 to 2200 F. It is oil hardening and is not recommended for carburizing. Its machinability is equivalent to standard low-carbon steels of the same hardness. Welding properties are excellent, especially for flash welding.

Mechanical properties as heat treated are given in TABLE 2. A general comparison of Hy-Tuf with standard steels is given in TABLE 3. Effects of low temperatures on impact values can be seen in *Fig.* 4.

ALUMINIZED STEEL: The combination of steel and aluminum to obtain the most desirable properties of each offers the designer an attractive material. Arm-

Fig. 4—Effect of temperature on impact properties of Hy-Tuf indicates good low-temperature service



co's Aluminized steel is basically sheet steel with an aluminum coat approximately 0.001-inch thick. Molten aluminum applied directly to the steel provides the surface characteristics of aluminum with the physical and mechanical properties of steel. Heat and corrosion resistance of this combination is better than of either metal alone.

Aluminized steel withstands temperatures up to 900 F without discoloration and up to 1250 F without destructive scaling. Above 900 F, however, the coating begins to alloy with the steel base forming a tight gray surface layer of iron-aluminum alloy refractory which remains. Under certain conditions the material has been used with temperatures to 1650 F.

Gages from No. 30 through No. 12 are available in widths up to 30 to 48 inches depending on the gage. Moderate forming, drawing and spinning operations can be performed without damage to the coating. Oxyacetylene, arc or resistance welding can be employed under proper conditions. Brazing and soldering follow practices for aluminum rather than steel.

HIGH WORKABILITY STAINLESS STEELS: Carpenter Stainless No. 10 is an entirely new stainless steel, developed to overcome the manufacturing difficulties associated with the rapid work-hardening of conventional 18-8 steels. The general type analysis is: Carbon 0.08% max.; chromium 16.00%; nickel 18.00%. Its chief characteristic is that it hardens very slowly from cold working. It is excellent for all types of parts requiring severe cold-heading or upsetting, especially those that must remain nonmagnetic after severe cold working. It can be readily blanked, formed, swaged, extruded, coined, and upset. It has corrosion resistance to a wide variety of organic and inorganic chemicals and foodstuffs, resisting nitric acid well, and sulphuric acid moderately.

Fig. 5—Battery filling machine nozzle showing effect of sulphuric acid on conventional 18-8 and No. 20

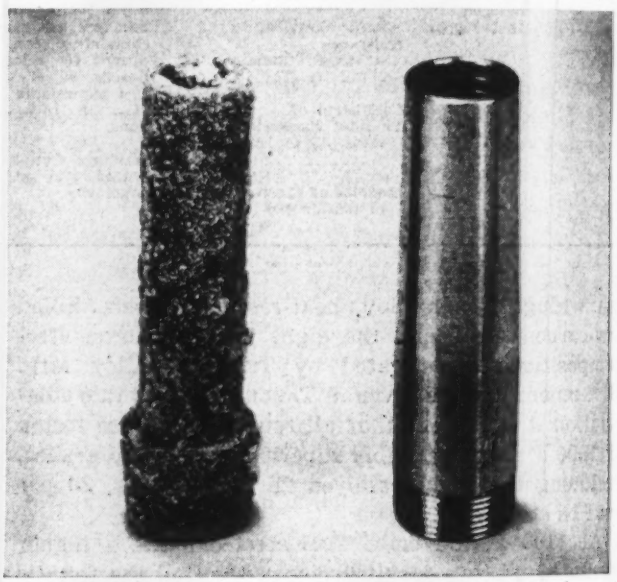


TABLE 5—CHARACTERISTICS OF NO. 20 STAINLESS

Forms	Corrosion Resistance	Physical Constants	Workability	Treatment	Mechanical Properties
Bars Strip Wire Billets Tubing Pipe Sheet Plate Special sizes, gauges, and shapes supplied on order.	Sulphuric acid: Highly resistant to most concentrations up to 176 F and up to concentrations of 10% or less (by weight) at boiling temperature. Fair resistance to hot, 75% acid. Corrosion negligible for all concentrations at room temperature. Nitric - sulphuric mixtures: Especially corrosion resistant. Arsenic, benzoic, carbonic, citric, fatty, maleic, oleic, picric, pyrogallic, stearic, tartaric, foodstuffs, vinegar, vegetable juices: Excellent — completely resistant. Halogen acids: Unsatisfactory — corrosion rates accelerated when bromides, iodides present.	Density Lbs/cu. in. ..... 0.289 Gms/cc ..... 8 Specific heat Btu per lb per F (32-212 F) .... 0.12 Gram-calories per gram per deg. C (0-100 C) ..... .12 Specific electrical resistance at 68 F: Ohms per cir mil ft 451 Microhms per cm cube ..... 75 Coefficient of Thermal Expansion Mean 68 F to 1200 F .... 9.4×10^{-6} Mean 20 C to 650 C .... 16.9×10^{-6}	sheet, and tubing, No. 20 can be welded without final annealing. Machinability: Machines with a tough chip, but not quite as stringy as types 302, 304, and 316. Machines with a somewhat better finish than most austenitic steels. Welding: Welds, brazes, and solders satisfactorily. Use electrodes of Carpenter Stainless No. 20. Annealing, as specified, is recommended after welding, forging or similar reheating during fabrication. But in forms of plate, least 1065-1095 C (1950-2000 F) and water quench for maximum corrosion resistance. Scaling: Safe scaling temperature in continuous service of 980 C (1800 F). Coldworking: Extremely ductile, can be readily blanked, deep drawn, formed and upset. Hotworking: Can be forged, upset, headed, and riveted satisfactorily. After hotworking, reheat to at	Forging: Heat uniformly to 1150-1230 C (2100-2250 F). Do not forge below 980 C (1800 F). Annealing: Heat to 1065-1095 C (1950-2000 F) and water quench. Brinell hardness about 180. Hardening: Cannot be hardened by heat treatment. Can only be hardened by cold work.	(Nominal) (1 in. round bar—annealed 1950 F and water quenched) Yield strength, 0.2% offset psi ..... 35,000 (Kg per sq cm)..... 2,460 Tensile strength (psi) 85,000 (Kg per sq cm)..... 5,975 Elongation in 2 in. (5.08 cm, %)..... 50 Reduction of area, % 65 Hardness (Brinell)... 180 Hardness (Rockwell B) 84

General characteristics of the steel are given in TABLE 4.

It is used for fastenings, such as cold headed bolts or screws with recessed heads, upset nuts, etc. This steel makes possible for the first time the commercial production of austenitic chrome-nickel nuts on automatic nut making machines. The lower work-hardness developed in No. 10 reduces the tendency of heads to crack and makes possible more drastic upsetting. In the production of a special rivet, type 303 (modified for cold-heading) and type 302 stainless had been used. With the switch to Stainless No. 10 this has been the record:

1. One heading machine gives the production of two
2. Die life jumped from 3½ to 45 hours
3. Scrap loss reduced from 12 to 3 per cent
4. Closer tolerances on heading and machining operations
5. Machining speeds are the same as for type 303, and tool life is the same.

A sulphuric acid resisting stainless steel, Carpenter No. 20 which is approximately the same in composition as Durimet 20 castings, is available for the first time in rolled forms. Type analysis of this steel is: Carbon 0.07% max.; manganese 0.75%, silicon 1.00%; chromium 20.00%; nickel 29.00%; molybdenum 2.00% min.; copper 3.00% min. It is licensed under the Duriron Company Inc. patents.

This stainless has excellent corrosion resistance to hot sulphuric acid, a property which distinguishes it from ordinary stainless steel. At a concentration of 78 per cent sulphuric acid (60 degrees Be), which is the most corrosive concentration of sulphuric acid, Stainless No. 20 is good up to a temperature of 125 F. In all other concentrations it is good up to temperatures of 176 F. In boiling sulphuric acid it has useful resistance in concentrations up to 10 per cent. In addition to its resistance to sulphuric acid, Carpenter Stainless No. 20 offers advantages of excellent physical properties and fabricating qualities. It compares favorably in first cost and in maintenance cost with other materials which can provide the necessary corrosion resistance. It has been found to increase equipment life and in many cases reduce the cost of fabrication. General characteristics of this material are given in TABLE 5.

Well adapted for use in machinery for the manufacture of synthetic rubber, high-octane gasoline, solvents, explosives, plastics, synthetic fibers, heavy chemicals, organic chemicals, pharmaceuticals, and food-processing equipment, Stainless No. 20 is finding typical applications as mixing tanks, heat exchangers, process piping, pump shafts and rods, valve stems, bolts, nuts, washers, tie rods, pickling racks, etc.

In a battery manufacturing plant nozzle assemblies to fill storage batteries with electrolyte on a production line are required to handle 12 per cent sulphuric acid (specific gravity 1.080) at temperatures from 78 to 130 F. Hard rubber nozzles broke

TABLE 6—CHARACTERISTICS OF FREE-CUT INVAR 36 ALLOY

Physical Constants	Workability	Treatment	Mechanical Properties
Thermal Conductivity Btu/hr/sq ft/in. thickness/deg. F +70 F to 212 F .....72.6 Cal/sec/sq cm/cm thickness/deg. C 21 C to 100 C .....0.025 **Specific Heat** Btu per lb per deg F (77 F to 212 F) .....0.123 **Thermoelastic coefficient** 60 F to 122 F ..+27 x 10^{-6}/deg. F 16 C to 50 C ...+50 x 10^{-6}/deg. C **Specific electrical resistance** annealed: 570 ohms/cir mil ft (95 microhms per cc) Cold drawn: 510 ohms/cir mil ft (85 microhms per cc) **Thermal coefficient of electrical resistance** 70 F to 212 F = +.0006/deg. F 20 C to 100 C = +.001/deg. C **Melting Point** ..... approx 2600 F (1425 C) **Specific Gravity** 8.05	**Machining** (Free-Cut Invar 36): Easy to machine on automatics to close tolerances with smooth finishes. Use same procedure required for cutting ordinary steels. **Blanking & Forming** (Invar 36): No unusual problems. Recommend Rockwell hardness of B-90 for cleanest blanking properties. For deep drawing, a finish annealed strip of Rockwell hardness B-75 is usually desirable. **Welding:** Can be welded successfully by usual methods. Invar 36 is better adapted to welding procedure than is Free-Cut Invar 36. **Cold Heading:** May be swaged or cold upset but Invar 36 recommended instead of Free-Cut Invar 36 for these operations. **Plating**—Can be chromium, cadmium and nickel plated or zinc coated by usual methods for ferrous alloys. **Grinding** — Silicon carbide wheel desirable, preferably a soft wheel which will wear without loading. For finish grinding, the grit should be No. 80.	**Forging** — Heat quickly and avoid soaking in the forge furnace. Temperature recommended is 1800 F (980 C).	**Tensile Strength (psi)** annealed .....65,000 cold drawn .....90,000 **Elastic limit, yield point (psi)** annealed .....40,000 cold drawn .....70,000 **Reduction of area (%)** annealed .....65 cold drawn .....60 **Elongation in 2 inches (%)** annealed .....35 cold drawn .....20 **Hardness** Brinell (annealed) .....125 Brinell (cold drawn) .....185 **Rockwell B (annealed)** .....70 Rockwell B (cold drawn) .....90 **Elastic modulus** annealed .....20,500,000 cold drawn .....21,500,000 **Izod Impact at** 90 Rockwell B (ft-lb) .....90 (Does not lose high impact values when tested at low temperatures) **Shearing strength at** 90 Rockwell B (psi) .....45,000 **Torsional Modulus** .....7,100,000 **Endurance Ratio (endurance limit ÷ ten str)** ..... approx 0.40

frequently, sometimes as many as ten a day, with shutdown for nozzle replacement running up to thirty minutes. Cost of a new rubber nozzle was $1.75. With a switch to 18-8 stainless, the breakage problem was solved, but nozzles corroded so badly in two weeks that they had to be replaced, *Fig.* 5. Stainless No. 20 nozzles, in operation many months, show no signs of corrosion and the cost is only $1.26 each for material and labor.

A new free-machining alloy, Carpenter Free-Cut Invar 36 overcomes problems encountered in conventional Invar and other low thermal expansion alloys, all of which are traditionally difficult to machine. Interchangeable with regular Invar so far as expansion properties are concerned, Free-Cut Invar 36 is a low-expansion 36 per cent nickel alloy with the following type composition: Carbon 0.12 per cent max.; manganese 0.35 per cent; silicon 0.20 per cent max.; nickel plus cobalt 36.00 per cent; selenium 0.20 per cent. TABLE 6 shows the general characteristics of the free cutting type as well as Invar 36 which is designed for forming and forging applications. Temperature characteristics are indicated by the chart in *Fig.* 6.

The uses of Carpenter Invar 36 and Carpenter Free-Cut Invar 36 are (1) for those jobs where it is desired to have a minimum amount of size change with change in temperature, and (2) for those applications in which it is desired to have a low-expansion alloy operating in connection with a high-expansion alloy, to cause a movement with change of temperature. Under the first heading come accurate measuring instruments, control instruments, measuring tapes, etc., which are subjected to changes in temperature, and in which expansion and contraction will seriously impair accuracy. Applications in this field include radio and electronic devices, airplane control parts, etc. Under the second heading fall bimetal, low-expansion struts for thermoswitches, rods for temperature regulators, compensating devices, etc.

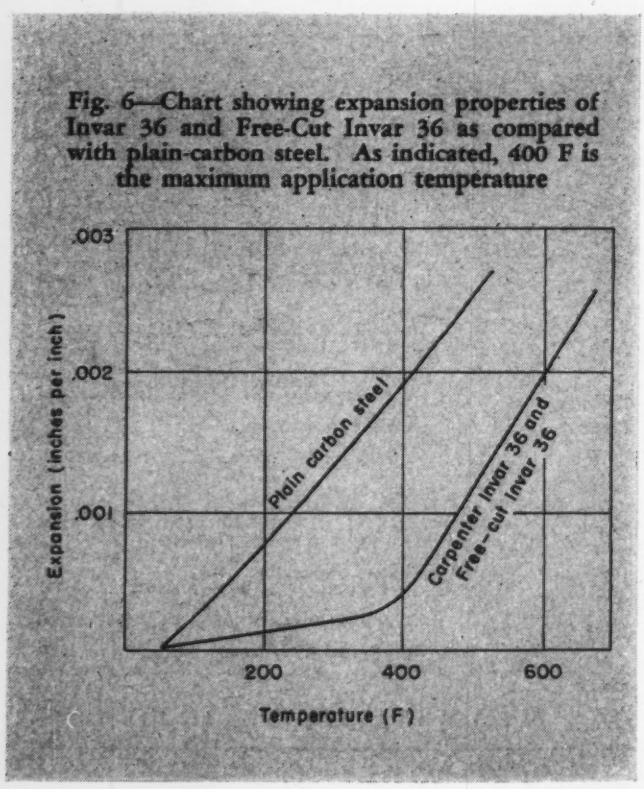


Fig. 6—Chart showing expansion properties of Invar 36 and Free-Cut Invar 36 as compared with plain-carbon steel. As indicated, 400 F is the maximum application temperature

PRECIPITATION HARDENING STAINLESS STEELS: The recent development of two types of precipitation-hardening stainless steel has greatly extended the field of application for stainless steels. Known as Armco 17-4PH and 17-7PH stainless steel, they have the unusual combination of excellent corrosion resistance, high strength and hardness, and good fabricating properties. In addition, these alloys are heat treated at temperatures of only 850-1400 F which eliminates many heat-treating problems. Both steels have a corrosion resistance approaching that of type 302 stainless and superior to the 400 series.

The new 17-4PH stainless steel, available in the form of bars and forging billets, can be heat treated at 850-900 F to a Rockwell C hardness of 40 to 45, an ultimate strength of 190,000 to 210,000 psi and a yield strength of 170,000 to 200,000 psi. These properties plus its corrosion resistance make the material especially suited for aircraft parts, bolts and fasteners, food and chemical processing equipment, springs, pump shafting, surgical instruments, and valve parts, *Fig.* 7.

Since only a light temper color forms on heat treatment and cracks and distortion are eliminated, parts can be finish machined before hardening. Additional advantages of the material are that it can be readily hot forged and has good machining and welding properties.

In the soft-temper condition 17-7PH sheet, strip and plate can be deep drawn or severely formed and then hardened to high strength and hardness. The heat treatment consists of 90 minutes at 1400 F, air or furnace cooling, then 30 minutes at 950 F, and slow cooling. Typical properties following this treatment are:

Ultimate strentgh (psi)	105,000 to 210,000
Yield strength (tension, psi)	150,000 to 190,000
Yield strength (compression, psi)	160,000 to 200,000
Elongation (% in 2 in.)	7-12
Hardness (Rockwell C)	40-45

Soft-temper 17-7PH can be readily welded by resistance, metal arc or atomic hydrogen processes. Highest weld efficiencies are obtained by welding before heat treatment.

Hard-temper sheet and strip require only a single heat treatment at 900 F to develop maximum strength and hardness. Typical properties developed are:

Ultimate strength (psi)	255,000
Yield strength (tension, psi)	250,000
Yield strength (compression, psi)	235,000
Elongation (% in 2 in.)	3
Hardness (Rockwell C)	51

Fabrication of hard-temper 17-7PH sheet and strip

is limited but it can be blanked, punched, flanged and dished. Welding is not generally recommended. The unusual combination of properties obtained in 17-7PH strip, sheet, and plate has met the requirements for such items as measuring tapes and rules, spring clips and washers, flat springs, food processing equipment, aircraft structural components, doctor blades, and plastic molds.

In wire form, 17-7PH stainless possesses the remarkable combination of high corrosion resistance and strength and elastic properties comparable to high-carbon spring steels. It is supplied in hard temper which can be formed, then brought to full strength and elasticity by a single heat treatment at 850 to 900 F or supplied precipitation hardened at the mill, extrahard temper. Mechanical properties of 17-7PH stainless steel wire in both conditions are:

	Hard Temper	Extra Hard Temper
Ult. strength (psi; 000)	200 to 285	244 to 345
Yield strength (psi; 000)	186 to 265	234 to 340
Hardness (Rockwell C)	40 and up	48 and up
Fatigue strength (psi)		
10,000,000 cycles		106,000
40,000,000 cycles		95,000

In both hard and extrahard tempers 17-7PH stainless steel wire is ductile enough to be wrapped on its own diameter. No stress relief is required for hard-temper material after fabrication and heat treatment, but if extrahard temper wire is formed it should be given a low-temperature stress-relief.

This new stainless steel wire is already being used for passenger and police car antennas, fishing rods, surgical instruments, and springs for fountain pens, window sash, valves, pumps, and food machinery. As a spring material it presents unlimited possibilities.

EXTRALOW-CARBON STAINLESS: Other relatively recent and important stainless steels are the Armco extralow-carbon grades. By providing lower overall cost compared with stabilized grades as well as greater corrosion resistance adjacent to welds, the ELC grades are being widely used for welded stainless steel structures.

The extralow-carbon grades have a maximum carbon content of only 0.03 per cent maximum as compared to about 0.10 per cent for regular grades. This exceptionally low carbon content prevents harmful carbide precipitation during welding and possible intergranular corrosion at the weld areas. Before the development of the extralow-carbon grades it was frequently necessary to anneal stainless weldments

LE 7—CARBON AND LOW ALLOYS ADAPTABLE CENTRIFUGAL CASTNGS IN PERMANENT MOLDS

...ations	—Nominal Analysis— C	Cr	Ni	Mo	Characteristics
...B, 49-8-1	0.25				General Structural welding grade.
...TM A-27-48, Grade 65-35					
... 0030					
...1040	0.40	1.00	...	0.25	High-strength, low-alloy steel.
...AVT F 49-8-1					
...TM A-148-48, Grade 90-60					
...8630	0.30	0.60	0.60	0.20	High-strength, low-alloy structural steel; heat-treatable.
...M A-148-48, Grade 105-85 .	0.30	0.60	0.60	0.20	High-strength structural alloys.
...M A-148-48, Grade 120-100	0.30	0.60	0.60	0.20	Heat-treatable.
...M A-148-48, Grade 150-125	0.30	0.60	0.60	0.20	Heat-treatable.
...M A-217, Grade WC-9 ...	0.15	2.40	...	1.00	High-temperature alloy to 1050 F, good creep resistance.
...TM A-157-44, Grade C-5A					
...9 9802	0.20	5.50	...	0.50	High-temperature alloy to 1100 F.

Fig. 7—The unusual combination of properties in 17-4PH stainless led to its use in the antishimmy damper at this aircraft landing gear

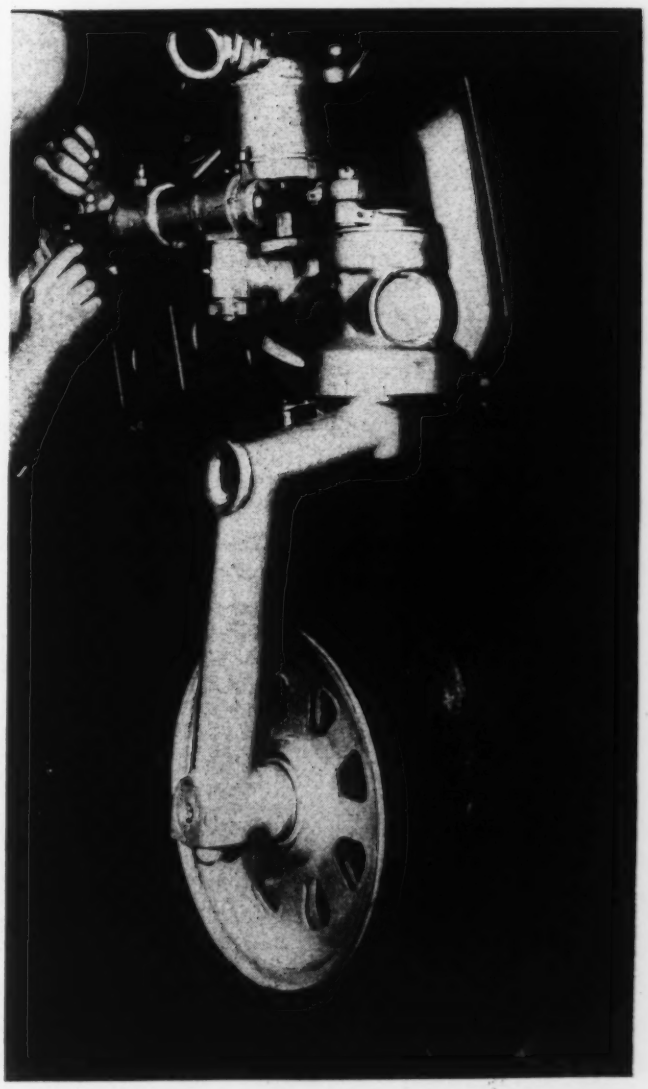


TABLE 8—HEAT AND CORROSION RESISTANT ALLOYS ADAPTABLE FOR CENTRIFUGAL CASTING IN PERMANENT MOLDS

Specifications	Nominal Analysis					Characteristics
	C	Cr	Ni	Mo	Others	
ASTM A-296-46T, Grade 10 AMS 5351 AISI 410	0.10	12.50	0.50	...	...	Heat-treatable.
ASTM A-296-46T, Grade 5. AMS 5363 AISI 347	0.07	19.50	10.50	...	Cb 0.80	Weldable grade for high-temperature applications.
ASTM A-296-46T, Grade 1. AISI 304	0.07	19.50	9.0	...	...	General corrosion - resistant alloy.
ASTM A-296-46T, Grade 4. Type 316	0.07	19.50	10.00	2.25	...	Corrosion - resistance and strength at moderately high temperatures.
ASTM A-296-48T, Grade 7.	0.15	24.50	13.50	...	...	Heat-resistant alloy.
Lebanon 34	0.07	20.50	28.50	...	Cu, Mo, Si	Highly resistant to sulphuric acid.
ASTM A-296-46T ..... AMS 5365	0.14	24.50	20.50	...	...	Heat and oxidation resistant.
AMS 5369	0.30	19.00	9.00	1.25	Cb, W, Ti	Heat-resistant.
H R Crown Max	0.25	23.00	12.50	...	W 3.00	Heat-resistant.
AMS 5767	0.15	21.00	20.00	3.00	Co 20.00, W, Cb	Heat-resistant.
ASTM A-296-46T ..... AMS 5365	0.20	25.00	20.50	...	...	Heat and oxidation resistant.

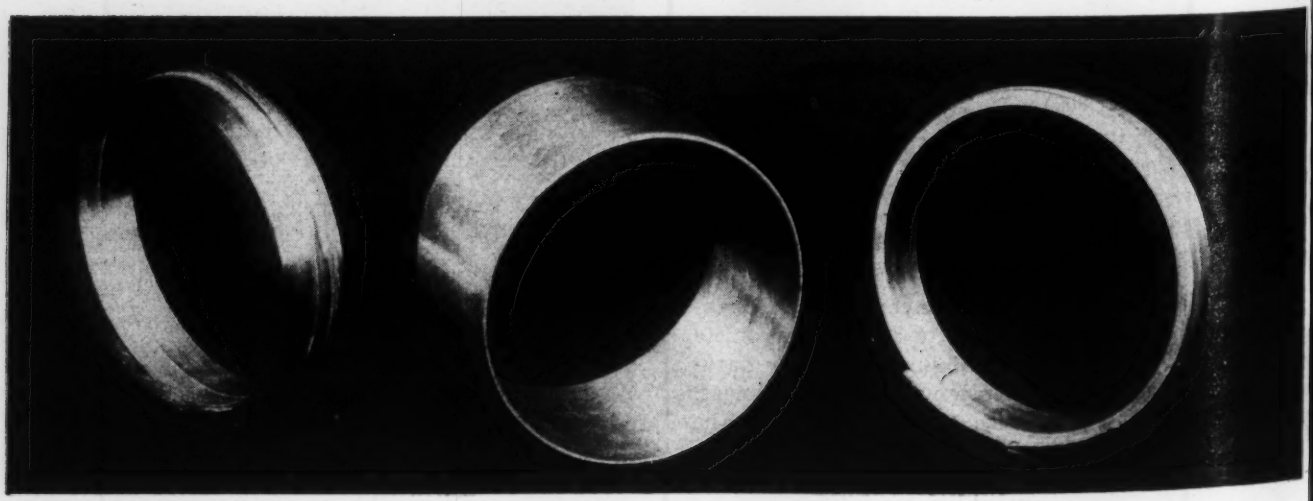
or use the more expensive stabilized grades to insure against corrosion in the weld area. Eliminating the necessity for annealing welds, except where required by codes, has permitted the fabrication of large assemblies on the job and has greatly simplified the problem of field repairs on stainless steel equipment.

Advantages of the extralow-carbon grades, types 304 ELC, 316 ELC, and 317 ELC, have led to their extensive use in chemical extraction tanks, sulfite digesters, welded pipe and pipe fittings for chemical processing plants, acid tanks, ducts and valves for handling corrosive gases, pasteurizers, and a wide variety of other applications.

Even more important, in the present period of material shortages, is the fact that these grades do not require critical columbium, titanium or tantalum to prevent harmful carbide precipitation due to welding. The NPA order prohibiting the use of columbium or columbium-tantalum bearing stainless steels except for DO orders, and only then if no other grade would suffice, has made the extralow-carbon grades vitally important. They have provided a satisfactory material which not only lowers cost and facilitates production but also frees critically short alloying elements for applications where they are essential.

Extralow-carbon grades cannot be used at service temperatures above 800 F inasmuch as prolonged exposure in the range of 800 to 1650 F will cause some carbide precipitation. The Boiler Code Committee of the American Society of Mechanical Engineers recently has issued a special ruling permitting the use of the extralow-carbon grades of austenitic stain-

Fig. 8—Typical heat-resistant rings centrifugally cast in permanent metal molds and finish machined to final shape



less steel (types 304, 316, 317) under the applicable section of their *Rules for Unfired Pressure Vessels.*

Electrical Steels: Greater efficiency can be obtained in wound core type transformers due to the recent development of improved oriented electrical steels. Armco Tran-Cor 3W and Tran-Cor 4W both have exceptionally low core loss and high permeability. Tran-Cor 4W has a core loss limit of only 0.64 watts per pound at 15 kilogausses and 60 cycles under the conditions recommended for its application. The corresponding limit for Tran-Cor 3W is 0.71 watts per pound.

These steels were developed for use exclusively in wound cores requiring thin-gage (12 mil) material. The excellent permeability of both grades permits their operation at inductions over 15 kilogausses and utilization of their low core loss.

Both steels are supplied in coils 1 inch to 30 inches wide and 0.012-inch thick only. Tran-Cor 3W and 4W are not recommended for stacked cores. The surface of the steel insures negligible interlaminar loss in distribution transformers even when cores are annealed. Since the steel comes fully annealed, a maxi-

TABLE 9—ENGINEERING PROPERTIES OF DUCTILE IRON*

ding Quality ..... Outstanding for capability of producing complex, intricate shapes.

ge of Castings Available ..... Thickness—0.1 in. to 50 in.
Weight —up to 200,000 lb

position ..... Broad range (%) C 3.2-4.2 Si 1.0-4.0 Mn 0.1-0.8 P 0.10 Ni 0-3.5 Mg 0.05-0.10

ile & Hardness Properties ...
inch sections)

Condition	Grade	Tensile Str (psi)	Yield Str (psi)	Elongation (% in 2")	Hardness (Brinell)
As-cast	90-65-02	95-105,000	70- 75,000	2.5- 5.5	225-285
As-cast	80-60-05	85- 95,000	65- 70,000	5.5-10.0	195-225
As-cast or drawn	70-50-08	72- 85,000	55- 62,000	9.0-15.0	170-195
As-cast	60-40-00	85- 95,000	65- 75,000	1.0- 3.0	230-290
Annealed (2.0-3.0% Si)	60-45-15	65- 75,000	50- 60,000	17.0-23.0	140-180
(1.0-1.3% Si)		55- 65,000	38- 42,000	21.0-23.0	130-140
(3.5-4.0% Si)		84- 89,000	66- 72,000	15.0-17.0	190-207
Quenched & drawn		120-140,000	90-110,000	4.0- 7.0	270-310
Quenched & drawn (limited data)		180-210,000	140-170,000	1.0- 3.0	330-420

pression Properties ..... Ratio of compression yield strength to tensile yield strength about unity.

ar Properties ..... Ratio of shear strength (in torsion) to tensile strength approximately 0.90.

dulus of Elasticity ..... Tension (psi) 24.5×10^6 to 26.0×10^6
Torsion (psi) 9.1×10^6 to 9.5×10^6

pact Properties ..... Charpy (ft-lb)

	As-Cast	Annealed	
Unnotched	15-40	70-85	(Grades 90-65-02, 80-60-05 As Cast)
Notched-Vee	2-5	10-15	(Grade 60-45-15 Annealed)

igue Strength ..... Ratio of endurance limit to tensile strength (data limited to strengths up to 100,000 psi)

	Unnotched	Notched (0.030 inch radius)
0.23 inch Dia. test bar	0.44/0.50	
1.0 inch Dia. test bar	0.34	0.26

rmal Expansion ..... 7.5×10^{-6} in./in./deg. F (70 F to 1100 F)

ecific Gravity ..... 7.1 to 7.2

nsity ..... 0.26 lb/in.^{3}; 450 lb/ft^3

chanical Wear Resistance ... Excellent in both the lubricated and unlubricated conditions. (All grades including annealed.) Equivalent to piston ring iron and superior to some bronzes.

chinability ..... Removal of 200 cu in. of metal and 0.030 inch land wear.
(Carbide Tools)

Cutting Speed, (fpm)			
As Cast	200-400	(Grades 90-65-02, 80-60-05)	
Annealed	600-900	(Grade 60-45-15)	

lding ..... Readily arc welded with Ni-Rod 55 or equivalent.

zing ..... Production of strong joints by silver soldering or brazing. Flow of solder on Ductile Iron intermediate between that on gray iron and steel.

d Surfacing ..... Variety of commercial hard surfacing electrodes readily applied by either acetylene or arc welding.

stance to Heat ..... Exceptional heat and growth resistance. Outstandingly superior to plain and alloyed gray iron.

ssure Tightness ..... Readily cast sound to produce completely pressure tight metallurgical structure.

ame Hardening ..... Flame hardens to 550 to 600 Brinell.
Induction hardens to 55 Rockwell C.

rdenability ..... End-quench hardenability curve similar to low alloy 0.40% C steel when quenched from 1550 F; hardness at quenched end 60 Rockwell C, hardness of 50 Rockwell C at 9/16 inch on Jominy bar. Increased hardenability when quenched from 1750F; hardness at quenched end 57 Rockwell C, hardness of 50 Rockwell C at 16/16 inch on Jominy bar.

rosion Resistance ..... Equivalent or superior to gray iron depending on corrosive conditions.

ctrical Resistivity ..... 55 to 70 microhms/cm/cm^2 at 70 F. (2.5% to 3.0% Si)

ting Range ..... 2050 to 2150 F.

*Courtesy International Nickel Co, Inc.

mum temperature of 1475 F will remove stresses produced by core winding.

Centrifugally-Cast Steels: With expanding defense requirements posing many new needs for circular and cylindrical parts capable of withstanding extremes of elevated temperature, comparatively recent developments in centrifugal steel casting in permanent molds have important implications for the design engineer, the foundryman and the ultimate user of cast metal products.

Among the general methods employed has been the Centri-Die process of Lebanon Steel Foundry, particularly adaptable to those types of steel which, by reason of their special properties, are difficult to manipulate by the more ordinary means of processing. From the engineering standpoint, advantages of permanent-mold centrifugal casting are: (1) Assurance of high-quality with maximum density and physical properties throughout; (2) readily achieved production of assorted parts and complex structural shapes which can not be satisfactorily cast by static methods; (3) ready use of alloys which are difficult or impossible to forge, due to extreme heat-resistance and hot-hardness.

It is worth noting that, almost without exception, all alloys adaptable to sand casting can be cast centrifugally. Definite improvement in mechanical properties is obtained with most metals when centrifugally cast. Generally, those alloys cast in permanent molds have superior properties, considering elongation and reduction in area, with less effect in yield strength evident. Some adaptable types of heat and corrosion-resistant steel alloys are designated in TABLES 7 and 8. Tolerances typical with sand castings largely prevail in the production of parts cast centrifugally.

Most centrifugal castings approximate a plain cylindrical shape but flanged rings or bushings can be

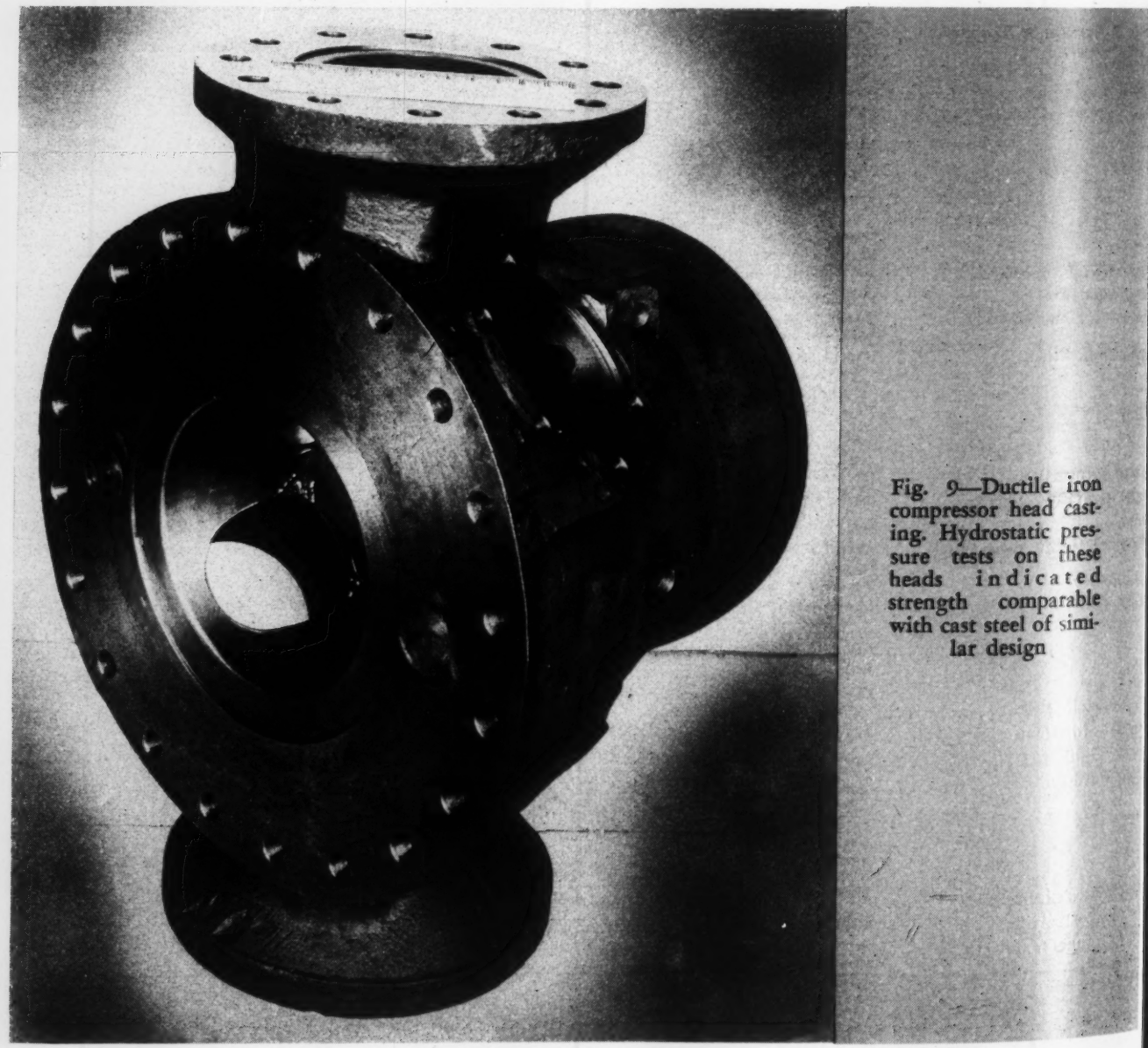


Fig. 9—Ductile iron compressor head casting. Hydrostatic pressure tests on these heads indicated strength comparable with cast steel of similar design

cast by this method. However, variations in the desired cross-section are generally achieved by machining, *Fig.* 7. Jet engine components produced in this manner include turbine shroud rings, turbine labyrinth seals, support rings, etc.

In the area of costs, centrifugally cast parts over 8 inches in diameter compare favorably with forged or rolled tubing. The larger the diameter, the more economical is the process.

Ductile Cast Iron: A fairly recent development which has been gaining favor rapidly, ductile cast iron brings to castings superior mechanical properties of considerbale design interest, *Fig.* 8. Ductile iron is basically a magnesium containing cast ferrous material* with graphite in spherical form. The typical notches and discontinuities of the matrix of gray iron which give rise to low strength and toughness are largely absent in ductile iron. Not only are ductility and toughness greatly improved but pressure tightness is excellent and machined finish resembles that of steel.

Complete tabular data on the properties of ductile iron are given in TABLE 9. With proper control it is possible to achieve a hard, chilled surface with a ductile core. Combinations of 52 to 60 Rockwell C hardness on the surface with 2 to 10 per cent elongation in the supporting metal can be produced. Size range of cast part possible is broad, sections up to 50 inches and weights to 200,000 pounds being the present maximums.

* U. S. Patents 2,485,760 and 2,485,761.

NONFERROUS

Aluminum Alloys: Several new alloys, new fabrication techniques, and an evergrowing list of engineering applications mark the advance of aluminum and its alloys. Giving timely and dramatic evidence of the growing use of aluminum, *Fig.* 10 shows a new PT boat with a half-welded, half-riveted aluminum hull.

NEW ALLOYS: Aluminum alloy developments are highlighted by a new experimental alloy, temporarily designated as "XA78S" by the Aluminum Company of America. Stronger than the highest-strength aluminum alloy now in use, it is presently being made available to plane builders for experimental and controlled production use only. Alloy XA78S was developed by modifying the same alloy constituents that were combined to produce the 75S alloy designed expressly to meet the needs of the aircraft industry in 1944. The main alloy composition is the same for both 75S and XA78S in that they are both of the aluminum-zinc-copper-magnesium family. However, XA78S is approximately 10 per cent higher in tensile and yield strengths than 75S, with about the same elongation and fatigue properties. Limited tests indicate that the increase in mechanical properties of XA78S will involve some sacrifice in workability.

For the present, the new alloy is confined to the production of sheet and plate—in both bare and Alclad forms—and extrusions. Manufacture of additional forms of XA78S will come as soon as production problems concerning the presently available forms are completely worked out.

A new light-metal casting material—ML aluminum alloy—has been developed by the Air Force for use in elevated-temperature operations. It has properties approximately one-third better than older ele-

Fig. 10—Right—A new PT-810 boat, built by Bath Iron Works, with aluminum hull, half-riveted and half-welded. Photo, courtesy U. S. Dept. of Defense

vated-temperature aluminum alloys. Aircraft castings, supports, and many other parts which formerly operated from 200 to 300 F will be designed in the future for temperature of from 500 to 600 F.

A summary of the properties of the new ML aluminum alloy is given in TABLE 10. The alloy has tensile, creep, and stress-rupture properties, at 600 F, approximately 35 per cent higher than other aluminum alloys which previously have been used for elevated-temperature service.

ALUMINUM AT LOW TEMPERATURES: Use of aluminum for extremely low temperature applications looks promising. Research has proved that aluminum becomes stronger and tougher at low temperatures, as compared with room temperatures, whereas certain other common metals become brittle when the temperature is lowered below some critical value. For example, tests show that welded aluminum plates become more resistant to shock loads as the temperature is lowered, even to as low as −300 F, whereas welded steel plates shatter at the lower temperatures. Its ability to withstand intense cold has resulted in the selection of aluminum by the Atomic Energy Commission for the construction of most of the equipment for producing liquid hydrogen in a new plant that will manufacture heavy water.

TABLE 10—MECHANICAL PROPERTIES OF ML ALUMINUM ALLOYS*

Test As-Cast	Temperature of Test	Prop
Typical tensile strength (psi)	Room	33,
Yield strength (psi)	Room	31,
Elongation (% in 2 in.)	Room	1.
Minimum tensile strength (psi)	Room	30,
Maximum tensile strength (psi)	Room	38,
Tensile strength (psi)	400 F	29,
Yield strength (psi)	400	27,
Typical tensile strength (psi)	600 F	18,
Yield strength (psi)	600	14,
Elongation (% in 2 in.)	600	9.
Minimum tensile strength (psi)	600	16,
Maximum tensile strength (psi)	600	17,
Tensile strength:		
After 2100 hr stabilization (psi)	600	14,
After solution heat-treatment and age (psi)	Room	44,
Machined (skin removed)		
Minimum creep rate (0.002%/hr)	600 F	4.
Stress rupture (100 hr, psi)	600	5,

* Nominal composition: 4% copper, 2% nickel, 2% magnesium, 0. manganese, 0.3% chromium, 0.05% vanadium, 0.1% titanium, in minum base.

Magnesium and Magnesium Alloys: First used in any significant quantity for flares and other pyrotechnics in World War I, magnesium has today become a first-rank structural material. As is generally known, magnesium is the lightest, commercially available structural metal, having a specific gravity of 1.8 compared to 2.7 for aluminum, 7.9 for steel and 4.5 for titanium.

Magnesium alloys have a modulus of elasticity of approximately 6,500,000 psi compared with approximately 10,000,000 psi for aluminum and 29,000,000

Fig. 11—Two jet-engine components cast from magnesium-rare earth-zirconium alloy ZRE-1 by Howard Foundry Co. Part on left measures 4 feet, weighs 155 pounds; part on right measures 18 inches, weighs 27 pounds

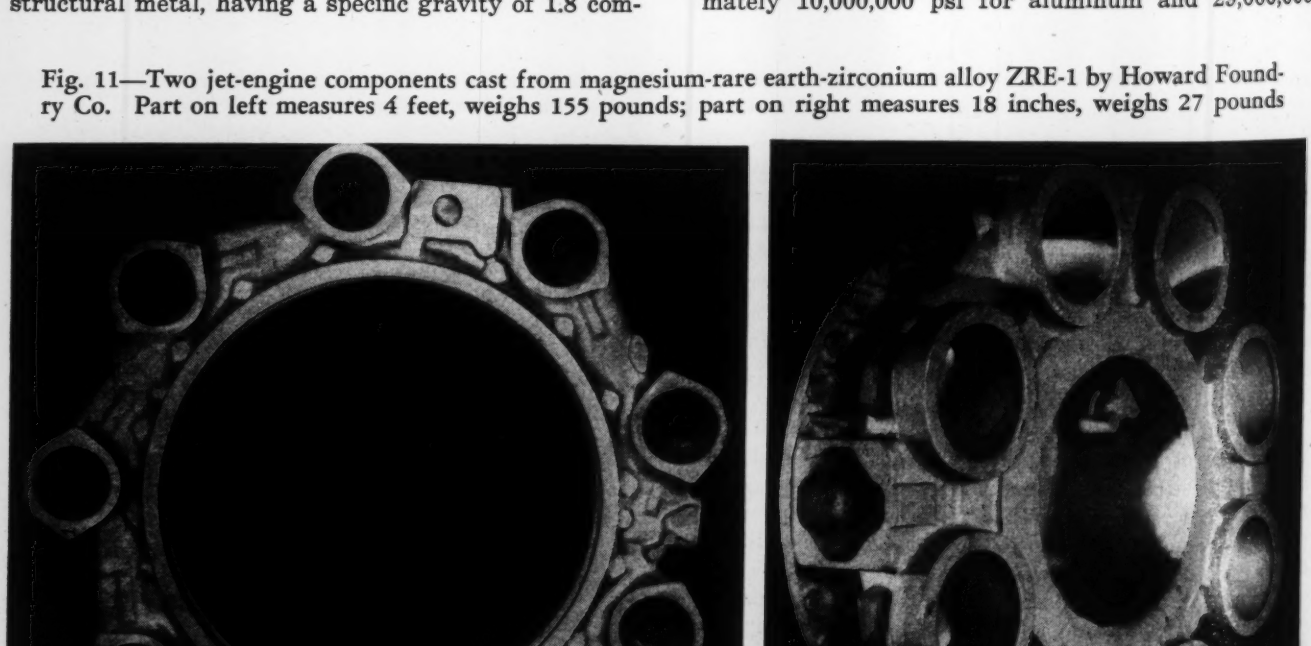


TABLE 11—PROPERTIES OF DOWMETAL C AND EK30*

	Temperature of Test (F)	Ultimate Tensile Strength (psi)	Tensile Yield Strength (psi)	Elongation (% in 2")	Creep† (psi)
	70	42,000	26,000	2.0	....
	400	16,900	10,900	36.0	900
	600	7,600	4,700	108.0	400
.....	70	22,900	16,500	2.4	....
	400	20,000	14,000	13.1	8,000
	600	11,800	7,800	69.6	1,300

*Properties are based on a few batches of separately cast test bars solution treated and aged.
†Stress required to give 0.1% creep in 100 hours at temperature.

TABLE 12—PROPERTIES OF Z5Z AND ZRE-1 ALLOYS

Property	Z5Z	ZRE-1
Ultimate tensile strength (psi)	40,000	24,000
Tensile yield strength (psi)	28,000	16,000
Elongation (% in 2")	9	4
Hardness (Brinell)	70	55
Fatigue:		
Unnotched (50x10⁶ cycles) (psi)	12,000	8,400
Notched (50x10⁶ cycles) (psi)	12,500	10,000

psi for steel. These alloys have a substantially higher damping capacity than aluminum alloys or wrought steel but not as high as gray iron castings. The fatigue strength of magnesium alloys is one of their better properties. Cast-magnesium alloys are, on the average, about 50 per cent higher in fatigue strength than cast aluminum alloys. However, the wrought alloys of each metal are approximately equal in fatigue strength. The notch sensitivity of magnesium alloys is about the same as that of aluminum alloys, but more than the steels and copper-base alloys.

Magnesium is not appreciably attacked by ordinary inland atmospheres. It is resistant to most alkalis, many organic chemicals—including hydrocarbons, some aldehydes, acetones, alcohols, phenols, amines, esters, and most oils—pure chromic and concentrated hydrofluoric acids, alkali-metal fluorides arsenates, chromates, and dichromates. It is affected in varying degrees by other acids and water solutions of salts, small changes in alloy composition being radically influential on corrosion rates.

RARE EARTH ALLOYS: Perhaps the most significant advance in magnesium alloys since World War II is the development and introduction of magnesium-rare earth alloys. The term *rare earth* identifies that group of similar trivalent metals with atomic numbers 57 to 71.

It has long been known that by alloying magnesium with rare earths, alloys having superior properties at elevated temperatures could be produced. The rare earth containing alloys which were first investigated had poor foundry characteristics and did not lend themselves to the production of castings of any great complexity. These early alloys were coarse grained leading to much trouble with hot cracking during solidification, and to breakage of the casting in processing it.

However, it was also well known that the element zirconium was a powerful grain refiner of magnesium alloys. This observation was first made by German research workers, whose investigations were terminated by the war, leaving it for others to develop the potentialities of this alloying element. The first important commercial exploitation of zirconium containing alloys was Dow's ZK60 alloy extrusions.

For several years the use of zirconium additions to magnesium-rare earth alloys to refine the grain has been the subject of intensive study. This work has culminated in the development of a new alloy, which is now offered to the industry on a commercial basis for sand-cast parts which combine good room-temperature properties with ability to perform at high stress levels in the range 300 to 600 F. The commercial development of these magnesium-rare earth-zirconium alloys came at an opportune time. New developments in the jet engine field have called for radical redesign of engine components. There has been a continued trend toward higher operating temperatures in jet engines. The result has been that a large field of application is developing for which the conventional magnesium-aluminum-zinc alloys would be unsuited. The excellent elevated-temperature properties obtainable with the magnesium-rare earth-zirconium alloys, in conjunction with their

Fig. 12—Miscellaneous mechanical parts fabricated from beryllium-copper strip and rod. Photo, courtesy Beryllium Corp.

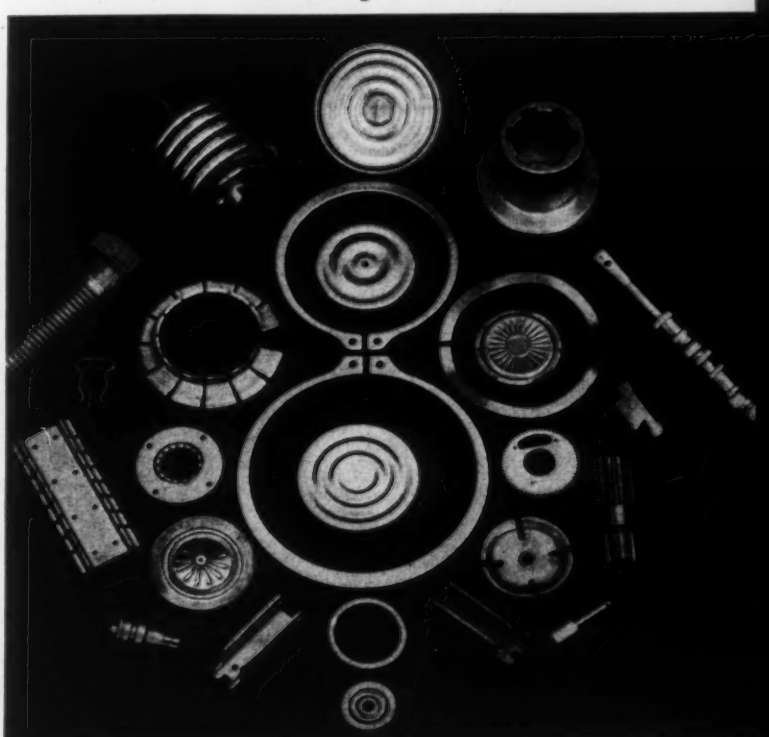


TABLE 14—PROPERTIES OF PHOSPHOR BRONZES*

Name	Form	Temper	Hardness (Rockwell) F	Hardness (Rockwell) B	Tensile strength (psi.)	Yield strength at ½% elong. under stress (psi.)	Elongation (in 2 in., per cent)	Endurance strength (100 million cycles, psi.)
Phosphor bronze, 5%	0.040" strip	0.050 mm anneal	73	26	47,000	19,000	64	
(Grade A)	0.040" strip	0.035 mm anneal	75	28	49,000	20,000	58	
	0.040" strip	0.015 mm anneal	79	34	53,000	22,000	50	
	0.040" strip	Half hard (21%)		78	68,000	55,000	28	
	0.040" strip	Hard (37%)		87	81,000	75,000	10	25,000
	0.040" strip	Spring (60%)		95	100,000	80,000	4	30,000
	0.100" wire	0.035 mm anneal			50,000	20,000	58	
	0.100" wire	Quarter-hard (21%)			68,000	60,000	24	
	0.100" wire	Hard (60%)			110,000		5	27,000
	0.100" wire	Spring (84%)			140,000		2	30,000
	1" rod	Hard (20%)		78	70,000	58,000	25	
Leaded phosphor bronze (Grade B)	1" rod	Hard (20%)		78	70,000	58,000	25	
Phosphor bronze, 8%	0.040" strip	0.035 mm anneal	80	50	58,000	23,000	65	
(Grade C)	0.040" strip	Hard (37%)		93	93,000	72,000	10	22,000
	0.040" strip	Spring (60%)		98	112,000		3	26,000
	0.100" wire	0.035 mm anneal			60,000	24,000	65	
	0.100" wire	Hard (60%)			130,000			
	0.100" wire	Extra hard (68%)			140,000			
Phosphor bronze, 10%	0.040" strip	0.035 mm anneal		55	66,000	28,000	68	
(Grade D)	0.040" strip	Hard (37%)		97	100,000		13	
	0.040" strip	Spring (60%)		101	122,000		4	
	0.100" wire	0.035 mm anneal			66,000		70	
	0.100" wire	Hard (60%)			147,000			
444 Bronze	0.040" strip	0.035 mm anneal	65	14	45,000	23,000	55	
	0.040" strip	Half-hard (21%)	96	68	58,000	40,000	24	
	½" rod	Hard (35%)		83	75,000	63,000	15	
	1" rod	Hard (25%)		80	68,000	57,000	20	
	2" rod	Hard (20%)		80	63,000	55,000	30	

* Courtesy, Chase Brass & Copper Co.

intrinsic light weight, provide an ideal answer to this developing need.

The Dow magnesium foundry now has available EK30 alloy as a composition suitable for their casting of production quantities of parts for high-temperature applications. The nominal composition of EK30 is 3 per cent total rare earths and 0.2-0.4 per cent zirconium. It is offered in the heat-treated and aged state. Properties of this alloy are shown in TABLE 11.

A few comments on the considerations leading to this choice of alloy are of interest. With respect to rare earth content, increasing quantities of rare earths up to 10 per cent or so will impart increasing creep strengths to the alloy. However, almost all this increase is accounted for by the first 2.5 to 3.0 per cent of rare earths contained. These alloys containing as much as 5 to 6 per cent rare earths are brittle in the as-cast state, leading to danger of breakage both in the foundry and by the user. In regard to foundry characteristics of the alloy, it is found that the higher rare earth contents give alloys having less favorable characteristics. Increased hot and cold cracking, lowered fluidity, increased segregation,

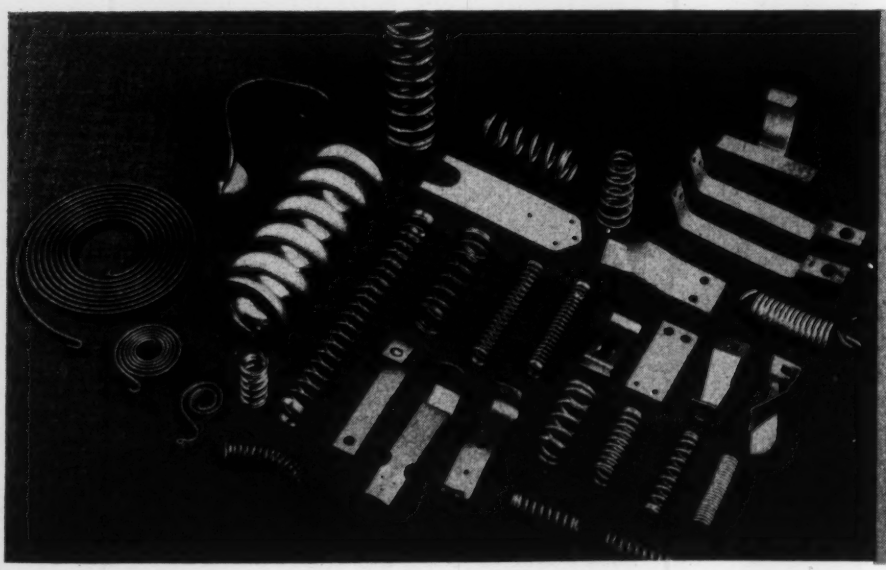


Fig. 13—Typical flat, contact, compression, brush, and power springs formed from beryllium-copper strip and wire. Photo, courtesy Beryllium Corp.

TABLE 13—AVERAGE MECHANICAL PROPERTIES OF TELLURIUM COPPER‡

Form	Temper	Size (in.)	Reduction of Area (Per Cent)	Tensile strength (psi)	Yield strength (at 0.5% extension under load, psi)	Elongation (in 2 in., per cent)	Hardness (Rockwell)
Round & hexagonal rod & square bar	Half-hard	¼	20	42,000	39,000	20	40B†
		½	20	42,000	39,000	22	40B
		1*	20	42,000	39,000	25	45B
		2**	15	42,000	39,000	35	45B
Round rod	Hard	⅛	45	54,000	50,000	9	50B†
		¼	45	54,000	50,000	11	50B†
		½	35	48,000	46,000	18	45B
		1	35	48,000	46,000	20	50B
Tube	Hard	2x¼	..	46,000	42,000	15	40B
Forgings	As-forged	..	..	33,000	8,000	..	40F

‡ Courtesy, Chase Brass & Copper Co.
* Round and hexagonal rod only. ** Round rod only. † On filed flat surface—round rod.

and greater tendency toward pitting are associated with the higher rare earth contents. Misch-metal, the source of rare earths, is costly and the amount consumed is approximately in proportion to the per cent rare earths in the alloy. The 3 per cent nominal rare earth-containing alloy, EK30, is therefore significantly more economical.

The function of zirconium as an alloying agent is to refine the grain, thereby imparting improved room-temperature mechanical properties and lowered hot-cracking tendency. As little as 0.1 per cent zirconium refines the grain markedly; greater quantities exert only a moderate additional effect on the grain size and mechanical properties and do not improve castability significantly. EK30 alloy can be melted on a large scale in premelting furnaces, starting with ingot materials. This alloy, therefore, lends itself much more readily to high productivity and low costs in the melting room and to accurate metallurgical control, than do the high-zirconium alloys. In the solution heat treated and aged condition, its properties compare favorably with those of the aged high-zirconium alloys.

Thus, EK30 has been selected as a standard composition on the basis of its desirable balance of mechanical properties at elevated and low temperatures, in combination with favorable production economy. It is advocated only for those applications in which high load carrying capacity at elevated temperatures is required. The magnesium-rare earth-zirconium alloys are not offered as substitute for magnesium- aluminum-zinc alloys, but serve only to expand the field for which magnesium-base alloys can be considered. Although EK30 alloy has many desirable characteristics, such as ease of producing pressuretight castings, such secondary characteristics can be attained more economically with the conventional magnesium-aluminum-zinc base alloys.

Two magnesium-rare earth-zirconium alloys developed in England are being used by Howard Foundry Co. for jet engine and other parts where a high strength-to-weight ratio is essential. Room temperature properties of these alloys are shown in TABLE 12. Two parts made from the ZRE-1 metal are shown in *Fig.* 11. The part on the left, for a jet engine installation, weighs 155 pounds, measures 4 feet in diameter. The part on the right, made of the same alloy, is 18 inches across and weighs 27 pounds.

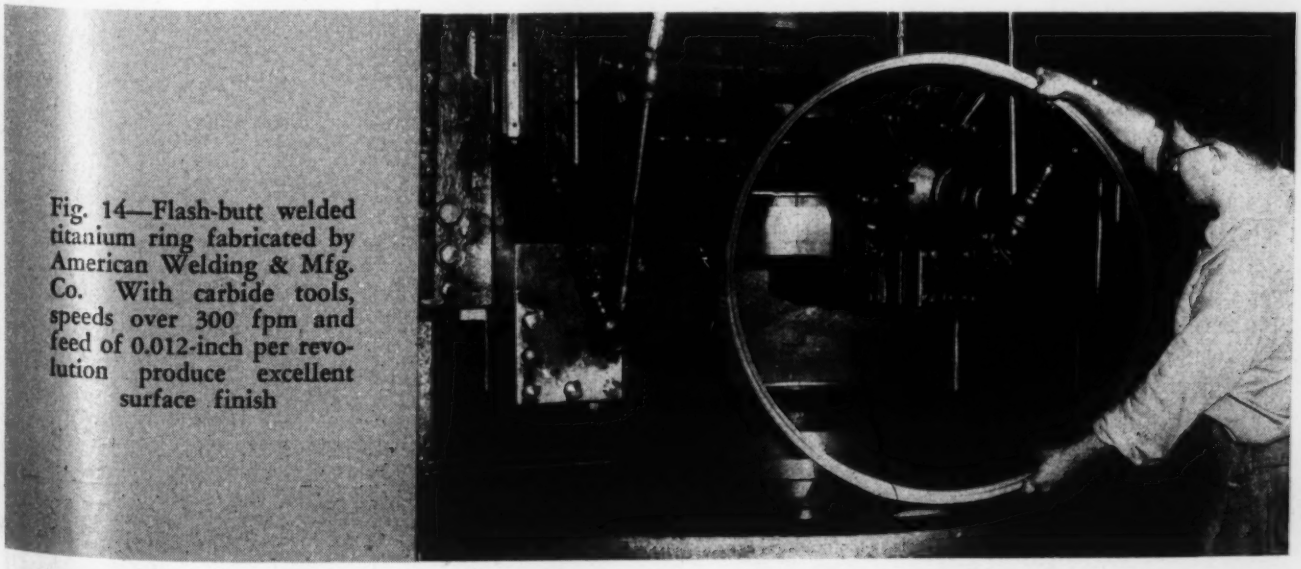


Fig. 14—Flash-butt welded titanium ring fabricated by American Welding & Mfg. Co. With carbide tools, speeds over 300 fpm and feed of 0.012-inch per revolution produce excellent surface finish

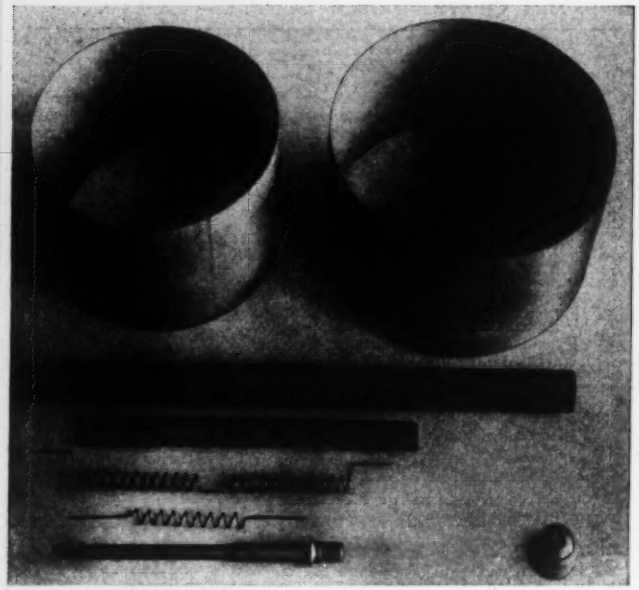


Fig. 15—Group of siliconized molybdenum parts for high-temperature applications produced by Fansteel Metallurgical Corp.

Copper and Copper-Base Alloys: Although no completely new alloys have been produced recently in the brass, bronze and beryllium-copper families, new working and finishing techniques and extended applications have been developed. The time-proved properties of these older materials, plus the several new features discussed in the following sections, merit the continuing appraisal of copper-base alloys by designers.

BRASSES AND BRONZES: Copper alloyed with zinc —brass—and copper alloyed with some hardening element such as tin, silicon or manganese—bronze—are the most extensively used of the coppers. They are, generally, easily worked into shape and possess a resiliency and toughness to withstand shock and strain. They do not rust, are generally resistant to corrosion from most (but not all) sources, and will take and hold a good finish. Although none of the brasses and bronzes may be hardened or tempered by heat treatment, greater tensile strength or hardness can be obtained by some form of cold working.

Properties of the numerous coppers, brasses and bronzes have been thoroughly disseminated and are readily available in the literature. Average mechanical properties of one of the more recent alloys which combines machinability with high electrical and thermal conductivity, tellurium copper, are given in TABLE 13. Mechanical properties of a representative group of phosphor bronzes are given in TABLE 14. This series is known for its high strength and resistance to fatigue, good ductility and resilience, and excellent corrosion resistance.

Formbrite Stock: A new process which can be applied to practically any copper alloy to obtain exceptionally good finishing characteristics good physical properties, and deep-draw qualities has been developed by American Brass Co. This process consists of a special process of rolling or drawing, plus a closely controlled heat treatment which imparts a very fine grain to copper-base metals. Brass treated by this method is termed "Formbrite" and is produced in sheet, strip, rod, wire, and seamless tube forms, at standard prices. Although now applied only to copper-zinc alloys, the process is said to be applicable to practically any copper-base metal. As a drawing brass in sheet or strip form, Formbrite is stronger, harder and more scratch resistant than its standard counterpart. In rod and wire form, the new material has about the same strength as regular cold-heading wire, plus good ductility.

Improved Copper Alloy Castings: A new copper oxide flux method of producing copper and copper alloy castings of increased physical properties has been developed in Great Britain. Basically, the process consists in using copper oxide to remove hydrogen from the molten metal. The presence of 0.0000022 per cent by weight of hydrogen in copper or copper-base metal produces voids totaling one per cent in the final casting. The process substantially reduces scrap losses caused by gas porosity in the castings.

BERYLLIUM-COPPER ALLOYS: New uses in both defense and nondefense fields are being found for beryllium copper, perhaps the most versatile copper alloy. A variety of parts fabricated from this material are

TABLE 15—TYPICAL MECHANICAL PROPERTIES BERYLLIUM COPPER*

Form and Temper	Tensile Strength (psi)	Elongation (in 2 in., %)	Hardn (Rockw
Strip			
Annealed	60- 80,000	35-50	B45-6
Annealed, heat treated	165-180,000	5-10	C36-4
1 No. Hard	73- 78,000	10-35	B86-9
1 No. Hard, heat treated	175-190,000	4-7	C38-4
2 No. Hard	80-100,000	5-15	B88-9
2 No. Hard, heat treated	185-200,000	2-5	C39-4
4 No. Hard	95-120,000	2-6	B94-9
4 No. Hard, heat treated	190-205,000	1-3	C40-4
Rod			
Annealed (0.020 to ¼-in.)	60- 85,000	35-50	B55-8
(over ¼-in.)	60- 85,000	35-50	B55-8
Annealed, heat treated (0.020-in. and over)	165-180,000	3-8	C36-4
Cold worked			
(0.020 to ¼-in.)	90-115,000	10-25	B88-9
(over ¼ to ⅜-in.)	95-120,000	10-25	B90-9
(over ⅜-in.)	80-100,000	10-25	B80-9
Cold worked, heat treated			
(0.020 to ⅜-in.)	185-215,000	2-5	C39-4
(over ⅜-in.)	165-190,000	3-6	C34-4
Wire			
Annealed	60- 80,000	35-50	
Annealed, heat treated	165-180,000	5-10	
1 No. Hard	90-110,000	10-25	
1 No. Hard, heat treated	175-190,000	4-8	
2 No. Hard	100-135,000	5-10	
2 No. Hard, heat treated	180-200,000	2-6	
3 No. Hard	125-145,000	2-5	
3 No. Hard, heat treated	185-210,000	2-4	
4 No. Hard	135-155,000	0-2	
4 No. Hard, heat treated	190-220,000	1-3	

* Courtesy, Beryllium Corp.

shown in *Figs.* 12 and 13. Typical mechanical properties of beryllium copper in strip, rod and wire forms are listed in TABLE 15. In TABLE 16 are given the average mechanical properties of alloy 20C, the most widely used alloy for investment castings.

Perhaps the most significant development is in the widespread use of beryllium-copper electrical connectors, sockets and terminals in automotive, aircraft, tank, and electronic applications. Beryllium copper best meets dependability and efficiency requirements through high strength combined with good formability and conductivity and, at the same time, excellent resistance to both vibrational fatigue and relaxation insures long service life. Other relatively new uses include sealing rings, retaining rings, and wave or spring washers. By virtue of its good resistance to wear and corrosion—together with high strength—beryllium copper offers many advantages in these applications.

Also of recent significance is the development of beryllium-copper drawing and forming dies for producing stainless-steel parts. These dies produce a good surface finish on stainless components. Depending on size and shape requirements, dies can be pressure cast or produced from bar stock. Similarly, beryllium-copper pressure-cast dies may offer important cost saving opportunities over short runs in die casting zinc alloys.

In chemical processing, beryllium-copper scraper blades are frequently specified to meet critical operating conditions. For example, it may be desirable to have a blade material of high hardness to operate in contact with a steel roll or drum. Since steel against steel may promote rapid wear, beryllium copper frequently provides the best answer. Although beryllium copper has for some time been employed as an electrode material for resistance welding by spot, seam and projection methods, it is now also finding use as an insert material for flash welder dies.

Other Alloys Containing Beryllium: Alloys of beryllium with zinc, nickel, and aluminum are now

Fig. 16—Typical metal-spraying setup for applying molybdenum bearing surfaces

available. The Illinois Zinc Co. is producing the zinc-copper-beryllium alloy developed by the General Electric Co. The properties of this heat-treatable alloy compare favorably with those of brass, and the use of zinc in place of copper gives it a cost advantage which may influence its use.

A 2.75 per cent beryllium-nickel alloy, heat-treatable to even higher strength and hardness than the beryllium-copper alloys, is being used in the production of cast diamond drill bits, precision castings, and, experimentally, dies for molding plastics. A 5 per cent beryllium-aluminum master alloy reported by the Brush Beryllium Co. is used by aluminum and magnesium foundries because of the great inhibiting effect of beryllium (as low as 0.006 per cent) on the inflammability and oxidation of magnesium. It also acts as a grain-refiner in aluminum castings. Some interesting experimental work is being done on beryllium additions to aluminum in cladding steels, the beryllium permitting the use of a thinner aluminum

TABLE 16—AVERAGE MECHANICAL PROPERTIES OF ALLOY 20C*

Properties	As Cast	Cast and Heat-Treated (2 hr. @ 650 F.)	Cast and Solution-Annealed	Solution-Annealed and Heat-Treated (2 hr. @ 650 F.)
Ultimate tensile strength (psi)	75,000-85,000	90,000-110,000	55,000-70,000	155,000-185,000
Proportional limit (0.002% offset)	20,000-30,000	25,000- 40,000	10,000-20,000	100,000-130,000
Yield strength (0.01% offset)	25,000-35,000	30,000- 45,000	15,000-25,000	110,000-140,000
(0.20% offset)	40,000-50,000	45,000- 65,000	20,000-40,000	130,000-160,000
(0.50% strain)	30,000-45,000	35,000- 55,000	20,000-40,000	55,000- 85,000
Elongation (% in 2 in.)	16-29	10-25	30-50	1-3
Reduction of area (%)	15-30	10-25	20-40	0-3
Hardness (Rockwell)	B80-90	B90-100	B60-80	C38-45
Hardness (Brinell)	150-185	185-240	107-150	352-426
Compressive properties (0.001 in. set)	.....	.....	.....	160-180,000
Endurance strength (at 10,000,000 cycles, psi)	.....	.....	.....	20- 30,000
Izod impact strength (ft-lb)	60-80	45-65	80-110	5-14
Electrical conductivity (% IACS)	12-17	17-22	10-15	20-25

* Courtesy Beryllium Corp.

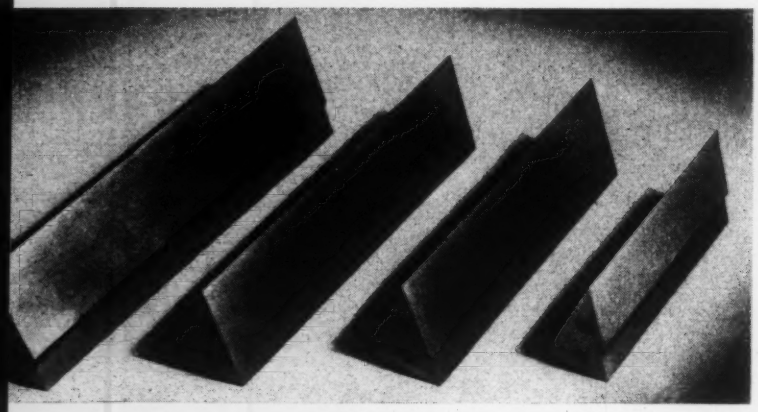


Fig. 17—Group of aircraft control counterweights made from Fansteel 77 Metal which is about 50 per cent more dense than lead

clad layer, and also improving its ductility and corrosion resistance.

Titanium and Titanium Alloys: For the last few years, titanium has been heralded as the answer to many engineering problems—and rightly so. Strength, light weight and corrosion resistance is the extremely desirable combination offered by titanium. Only about double the weight of aluminum, yet four times as strong, the material is also less than half the weight of stainless steel and almost as strong. TABLE 17 gives average room-temperature properties of commercially pure titanium and several of its alloys made by Rem-Cru Titanium Inc. Physical properties of two early titanium alloys produced by R. G. Mallory and Co. Inc. are compared with three common structural alloys in TABLE 18. Titanium alloys now in the development stage look even more attractive.

Availability and price are both on the darker side of the titanium picture. By the end of 1952, it is expected that Titanium Metals Corp. of America's new plant will be producing about 4000 tons per year. The only commercially feasible method of extracting the metal at present is the Kroll process—basically a low-volume and costly procedure. A Canadian company has been reported able to produce titanium by direct reduction of titanium dioxide with calcium metal, but not much more cheaply. Reports from this country indicate that the present prices of $5 per pound for titanium sponge, $7 for ingot and $15 for sheet, in quantity, may be cut substantially in the forseeable future.

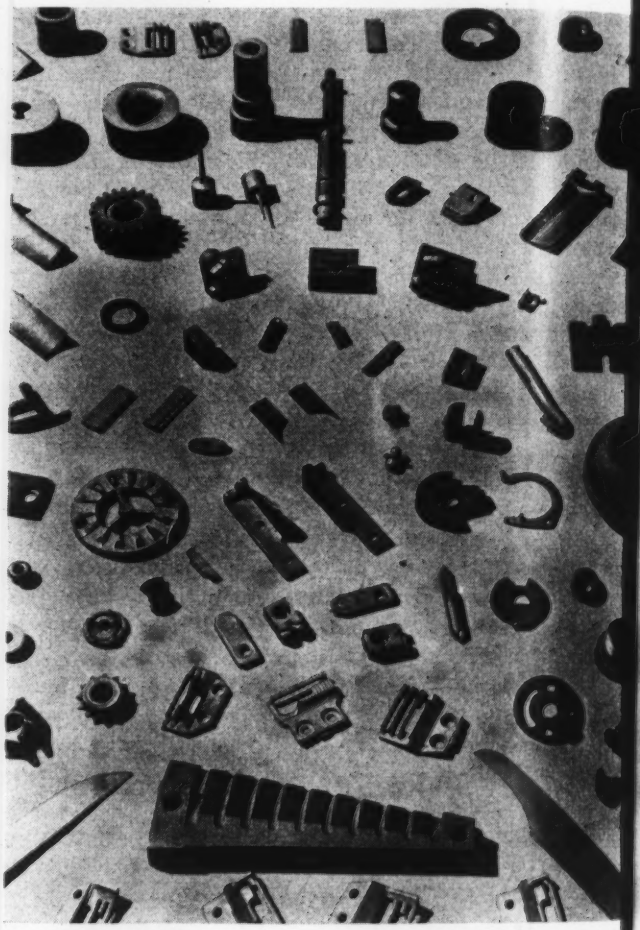


Fig. 18—Group of miscellaneous investment-cast Tantung parts showing intricate design and size variation

Another drawback of titanium is its embrittlement

TABLE 17—AVERAGE ROOM TEMPERATURE PROPERTIES OF REM-CRU TITANIUM AND TITANIUM ALLOYS

Property	Commercially Pure Titanium RC-55 Sheet	Commercially Pure Titanium RC-70 Sheet	Titanium Base Alloys RC-130-A Sheet	Titanium Base Alloys RC-130-B Forged Bar
Ultimate tensile strength (psi)	75,000	90,000	150,000	145,000
Tensile yield strength (psi)	65,000	80,000	140,000	135,000
Proportional limit (psi)	50,000	52,000	105,000	105,000
Modulus of elasticity (psi)	15,500,000	15,500,000	15,500,000	15,500,000
Elongation (%)	25	20	12-15	15-20
Bend radius (sheet)	1.5-2.0T*	2.0-2.5T	1.5-3.0T	....
Creep strength at 10^{-4}%/hr (psi)	.....	55,000	110,000	115,000
Fatigue endurance limit (psi)	.....	50,000	75,000	80,000
Impact strength (ft-lb, bar)	.....	15	.....	13

* T=sheet thickness.

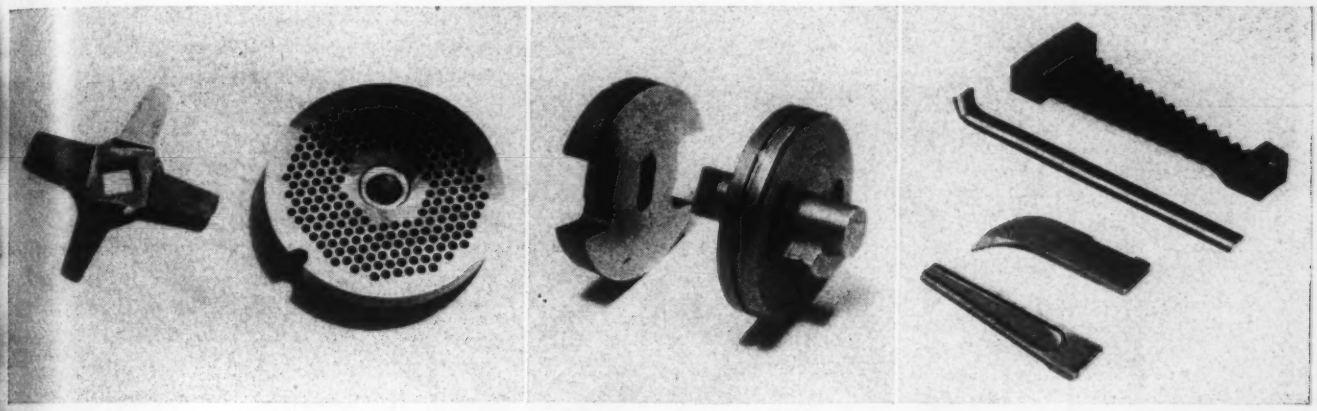


Fig. 19—Cast Tantung parts including a pair of rotary air valves, power food chopper blades, and turbine blade guide

and loss of strength on continued exposure to temperatures above 1000 F. While this temperature is far above the service range for aluminum, it does not approach the operating area of the high-temperature alloy steels. Also pure titanium tends to creep—a deficiency that can generally be modified by both cold working and alloying.

Most titanium produced is in the form of forgings. However, the metal and its alloys can be welded and hot worked and have good resistance to oxidation. They machine similarly to stainless steels, such as 18-8, and can be turned, drilled and tapped. Carbide tools are recommended and about the same feeds and speeds as for stainless.

Suitable uses of titanium and its alloys are practically unlimited. Aircraft applications include parts in jets and gas turbine engines, *Fig.* 14. Corrosion resistance makes the material ideal for many naval uses. Substituting a titanium alloy, thickness for thickness, for alloy-steel armor in military applications, with a weight reduction of about 40 per cent, has been discussed.

To many designers in industry today, titanium must perforce remain a material of tomorrow. However, the impetus given titanium developments by the current preparedness program will, without question, increase availability of this desirable metal and place it in a more competitive position with other structural materials.

Molybdenum: Long used as an alloying element with other metals and as grids, filaments, and electrodes in the electrical industry, molybdenum in its essentially pure form has recently been coming into use as a structural and bearing material. Molybdenum is produced by a rather complex process. Small amounts of impurities have a very adverse effect on the ductility and workability of molybdenum. For this reason, and because of the high melting point, the metal is extracted by a series of chemical purification processes, reduction to metal powder, compacting and sintering. Sinterings of the metal and its alloys are being produced measuring 6 inches square by 4 feet long and weighing over 400 pounds. Cast molybdenum ingots up to 6 inches in diameter and weighing 190 pounds are also available. The sintered or cast metal can be rolled into bar, rod or sheet, extruded, spun, drawn or cold formed.

TABLE 18—COMPARATIVE PROPERTIES OF TITANIUM AND OTHER FORGED METALS

Property	Mallory Titanium Alloy L-2749	Mallory Titanium Alloy L-2748	Cold Rolled Steel SAE 1010	Stainless Steel Type 302	Aluminum Alloy 24ST
Ultimate tensile strength (psi)	90,000	165,000	55,000	90,000	70,000
Yield strength (0.2% offset, psi)	75,000	153,000	25,000	35,000	41,000
Elastic modulus (psi)	16,300,000	18,000,000	30,000,000	29,000,000	10,000,000
Elongation (% in 2 inches)	18	10	20	50	15
Endurance limit, fatigue (psi)	63,000	95,000	.....	.....	18,000
Linear thermal coefficient (C)	10.4×10^{-6}	9.0×10^{-6}	13.5×10^{-6}	18.0×10^{-6}	23.2×10^{-6}
Density (lb/cu in.)	0.16	0.16	0.28	0.29	0.10
Ultimate strength density	562,000	1,030,000	196,000	310,000	700,000
Elastic modulus density	102,000,000	112,000,000	107,000,000	100,000,000	100,000,000
Electrical resistivity (microhm/cm)	60	140	10	73	6
Hardness (Rockwell A)	62	71	44	50	45

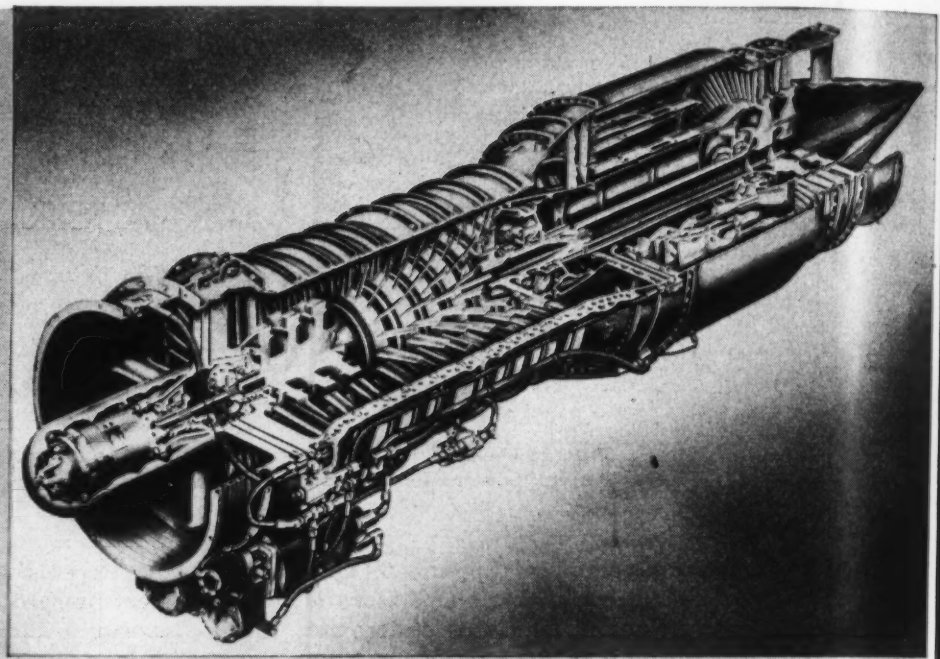


Fig. 20—Right—Cutaway view of J-34 Westinghouse jet engine showing Haynes alloy 36 cast turbine blades and nozzle vanes

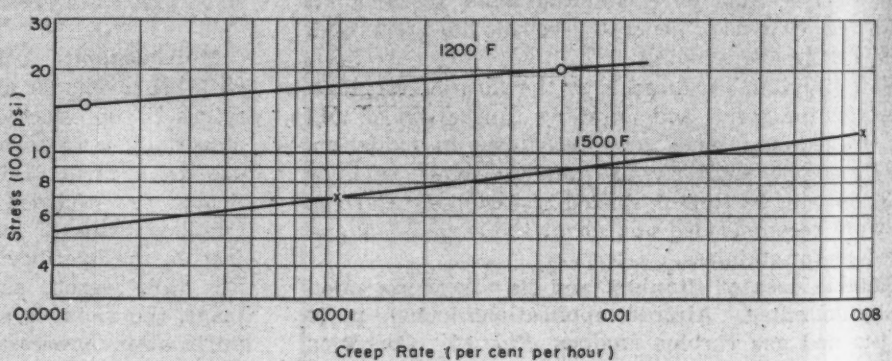
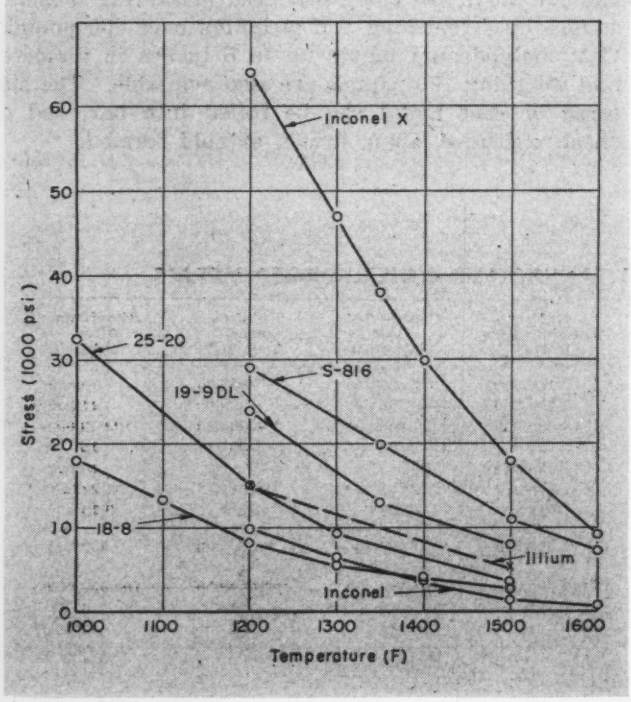


Fig. 21 — Right — Curves of stress versus creep rate for Illium at two temperatures

Fig. 22—Below—Curves of stress to produce a creep rate of 0.0001 per cent per hour versus temperature for Illium and various other alloys



Welding has not proved satisfactory yet, but brazing is being accomplished, preferably with nickel in the brazing alloy. Typical mechanical properties of molybdenum are included in TABLE 19.

SILICONIZED MOLYBDENUM: Since molybdenum, along with tungsten, is one of the best known of the refractory metals (i.e., metals having melting points above 3600 F) and has the ability to retain strength and stiffness where most metals would fail, its potential use in large parts for engines has become of great interest. Protecting the surface of molybdenum parts against oxidation at high temperature has been the chief problem in successful application of such large parts.

A process has been developed by Fansteel Metallurgical Corp. for coating molybdenum parts to protect against the destructive effects of oxidation at high temperatures. This coating, a molybdenum silicide, is different from the vitreous or ceramic coatings previously used. The siliconized coating is not only impervious to oxygen, but appears to resist attack by nitrogen, carbon dioxide, carbon monoxide or the sulphurous or hydrocarbon atmospheres com-

monly resulting from combustion. This development offers what is essentially a new material for use in air or combustion atmospheres, either reducing or oxidizing, at temperatures up to 3000 F.

Life of the coating is a function of temperature. From extended tests, life which may be expected in still-air under conditions of no mechanical stresses or loads varies from 6000 hours at 1500 F to 50 to 300 hours at 3000 F. Although the coating is extremely hard, coated molybdenum pieces can be worked to a limited extent at high temperatures.

Commercial applications of siliconized molybdenum probably will be made in the temperature range between 2000 and 3000 F, beyond the range of nickel-chromium and similar alloys. The upper limit is imposed by the melting point of the molybdenum silicides.

Limiting applications to some extent is the fact that the siliconized coating is not recommended for use at high temperatures in contact with molten glass or with strong alkalis, such as sodium hydroxide or lime. Also, the coating is not recommended at high temperatures in contact with a number of metals and alloys, including copper, iron, nickel, cobalt, chromel, nichrome and stainless steels. Siliconized coating is not recommended for wire smaller than 0.030-inch diameter when such wire is intended for prolonged service as resistance heating elements.

At present, siliconizing is done with laboratory equipment which imposes limitations on sizes. On fabricated parts it is recommended that all forming, fabricating and assembly be finished before siliconizing is done. This includes even simple bending or coiling. Rods, bars or wire with siliconized coatings are available in lengths up to 30 inches. Longer lengths of wire can be coated when wound into coils

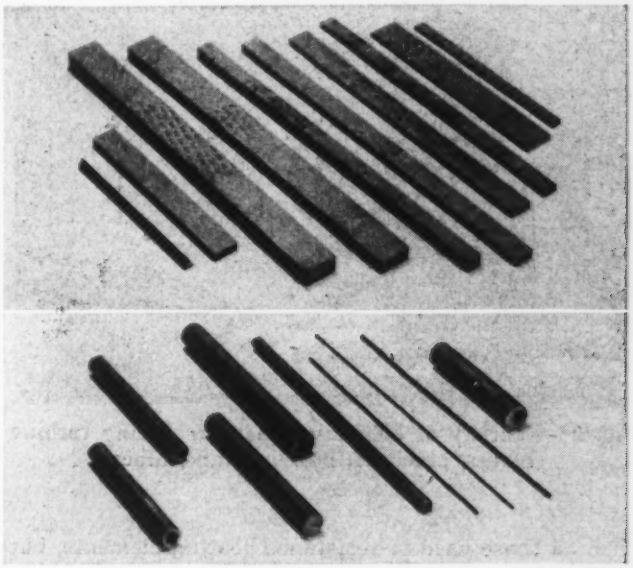


Fig. 23—Above—Extruded carbide rectangles, triangles and tubes produced by Vascoloy-Ramet Corp.

Fig. 24—Below—Group of miscellaneous shapes produced from Kentanium, a titanium-carbide material

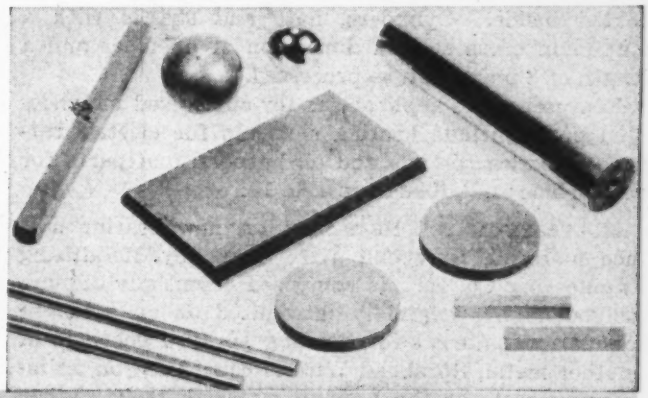


TABLE 19—TYPICAL MECHANICAL PROPERTIES OF TUNGSTEN AND MOLYBDENUM†

Form	Tungsten			Molybdenum		
	Tensile Strength (psi)	Elongation (% in 2 in.)	Hardness (Rockwell)	Tensile Strength (psi)	Elongation (% in 2 in.)	Hardness (Rockwell)
Rod—0.250"	70,000	0	37C	75,000	5	90B
Rod—0.100"	150,000	0	40C	100,000	5	97B
Rod—0.050"	200,000	0	44C	120,000	5	100B
Rod—0.050" annealed	.....	.	...	90,000	15	95B
Wire—0.025"	225,000	0	44C	130,000	5	100B
Wire—0.25" annealed	.....	.	...	100,000	15	95B
Wire—0.010"	250,000	0	...	170,000	1	24C*
Wire—0.010" annealed	.....	.	...	125,000	15	100B*
Wire—0.005"	300,000	0	...	190,000	1	....
Wire—0.005" annealed	.....	.	...	140,000	15	....
Sheet—0.040"	120,000	0	44C*	120,000	1	23C*
Sheet—0.040" annealed	.....	.	...	85,000	4	95B*
Sheet—0.020"	200,000	0	45C*	165,000	1	26C*
Sheet—0.020" annealed	.....	.	...	125,000	7	95B*
Sheet—0.010"	300,000	0	47C*	175,000	1	27C*
Sheet—0.010" annealed	.....	.	...	130,000	7	95B*

† Courtesy Fansteel Metallurgical Corp.
* Converted

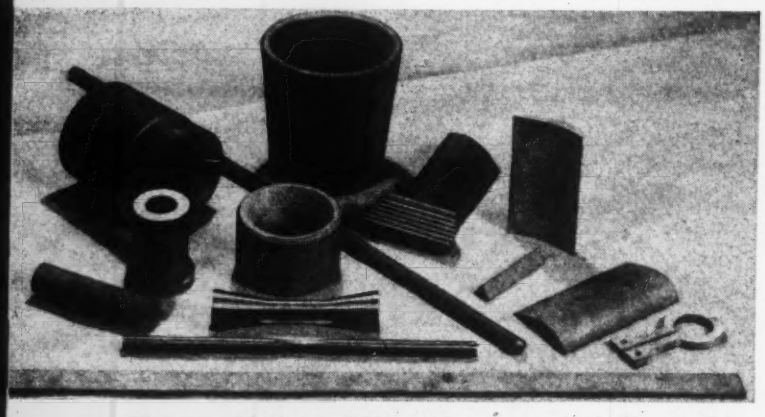


Fig. 25—Variety of Kentanium parts including turbine blades, crucibles, bushings, and tubes

such as those used in resistance heating elements, but the total length of the coil should remain within 30 inches.

Tubing, in diameters up to 2 inches and lengths up to 30 inches, can be coated both inside and outside. Small-diameter tubing with closed ends, such as thermocouple wells, has not yet been successfully coated inside. Cylinders, flats and shapes with a maximum cross section dimension of 6 inches and a length of 8 inches can be processed.

Representative applications for siliconized molybdenum parts include heating elements for electric furnaces, nozzles for gas and oil burners, and parts for gas turbine and jet engines, *Fig.* 15.

MOLYBDENUM FOR BEARINGS: A new bearing surface material, Sprabond Wire, made by Metallizing Engineering Co. Inc., is composed essentially of pure molybdenum. Originally introduced as an adherent foundation material for bonding sprayed coatings of another metal, Sprabond Wire is being used on an increasing scale as the bearing material itself. When sprayed, it bonds well to any clean or polished metal surface. Applications to date have proved extremely attractive from a design standpoint, in some cases bearing life being 25 times that of conventional bearing materials. *Fig.* 16 shows the spraying operations being performed on a lathe setup.

Tungsten and Tungsten Alloys: Like its related metal, molybdenum, tungsten is one of the most extensively used of the refractory metals. Tungsten has the highest melting point of any metal, 6152 F, and of all elements, except carbon. Most uses of this metal and its alloys hinge on its high melting point and its strength and stiffness at high temperatures. Properties are given in TABLE 19.

One of the latest tungsten alloys, Fansteel 77 Metal, is characterized by its high density, which closely approaches that of pure tungsten. The alloy is principally tungsten, with other metals added to impart machinability and other desirable physical properties. It is designed for use wherever maximum density, mass or inertia is required in limited space. Readily machinable, easily brazed or silver soldered by conventional methods, Fansteel 77 Metal is available in rods, bars or slabs or as powder-metal parts.

Although the density of Fansteel 77 Metal is exceeded by that of pure tungsten, gold and platinum, the utility of these metals is limited. Pure tungsten is relatively difficult to form and machine, and the cost of gold or platinum usually prohibits their use. Properties of Fansteel 77 Metal alloy are given in TABLE 20.

This alloy has been applied in rotors, flywheels, governors, balance weights, etc., where it is necessary to gain the maximum effect of rotational control within a confined space. The counterweights for aircraft controls shown in *Fig.* 17 are made of this alloy and have a density almost 50 per cent greater than lead, plus good strength and machinability.

Absorption of X-rays and gamma radiation is generally directly proportional to the density of the absorbing material. In this respect, Fansteel 77 Metal is approximately 1.5 times as effective as lead. Bombs or capsules of this alloy are easily made, are durable and require less wall thickness than lead to obtain equivalent radiation absorption.

TABLE 20—TYPICAL PROPERTIES OF FANSTEEL 77 METAL

Density (lb per cu in.)	0.603
Hardness (Rockwell C)	20 - 25
(Brinell conversion from Rockwell C)	230-225
Electrical conductivity (% IACS.)	11 - 15
Tensile strength (psi.)	90,000
Elongation (% in 2 inches)	1
Transverse strength (psi.)	185,000

Heat and Corrosion-Resistant Alloys: Cast cobalt-chromium-tungsten-carbon alloys, such as Tantung and Stellite, had their development primarily as cutting tools. Incidental to their cutting quality, which stems from the ability of these alloys to retain hardness at higher temperatures than does high-speed steel, their chemical composition confers upon these metals the property of resistance to oxidation, corrosion, and abrasion. These cast alloys, as the term implies, are melted and cast into molds and the range in intricacy of shapes as well as size is very broad, *Fig.* 18. Manufacturers of these alloys have produced a wide variety of compositions which vary in properties, especially in hardness, ranging from those which are of tool quality and quite unforgeable to others which can be forged and rolled.

TANTUNG: The wear and corrosion-resistant alloy, Tantung made by Vascoloy-Ramet Corp., is not amenable to heat treatment to the degree understood in the case of high-speed steels but is influenced by the rate of solidification. The producer thus can vary the product by the use of different casting methods. These range from metal molds, graphite molds and sands of various types to investment castings. The hard cast alloys of this type are likely to show a resistance to abrasion from 2 to 10 times that

TABLE 21—HAYNES STELLITE ALLOYS OF RECENT DEVELOPMENT

Alloy Designation	Nominal Chemical Composition (per cent)	Average Properties: Specific Gravity	Coefficient of Thermal Expansion (F. × 10⁻⁶)	Ultimate Strength (psi)	Yield Strength (psi)	Elongation (per cent)	Elastic Modulus (psi)	Hardness (Rockwell)	Form	Characteristics and Applications
25 (L-605)	20 Cr-15 W-10 Ni-0.1 C-Bal Co	9.15	8.30	150,000	72,000	60	35.3	C 20	Wrought	Primarily high-strength high temperature alloy. Superior at 1500 F and above. Exceptional formability and corrosion resistance.
36 (L-251)	18 Cr-15 W-10 Ni-0.4 C-0.05 B-Bal Co	9.04	7.97	105,000	50,000	3	33.8	C 30	Cast	Extremely high creep strength and stress-rupture properties at 1300 F-1800 F. High-temperature service castings such as turbine buckets, guide vanes, nozzles, etc.
42	Cr-Co-W-Bal Ni	8.78	...	20,000	.....	..	...	C 60	Weld Deposit	Low melting point, hard-facing alloy for gas deposition. Developed to withstand severe abrasion, moderate shock.
88	15 Ni-12 Cr-2 Mo-0.5 W-0.6 Ti-0.05 B-0.08 C-Bal Fe	7.96	10.73	104,000	85,000	32	30	B 100	Wrought; hot, cold-worked	Wrought, low-alloy content material with excellent creep-rupture properties below 1400 F. Developed for bolts, turbine disks, rims and buckets.
Hastelloy F	24 Fe-22 Cr-6 Mo-2 CbTa-0.05 C-Bal Ni	8.22	8.91	110,000	50,000	50	29	B 86	Wrought	Withstands mineral acids and salt solutions. Excellent resistance to chemicals which tend to pit.
90	27 Cr-3 C-Bal Fe	7.35	8.4	75,000	.....	0	...	C 57	Cast	Good abrasion resistance as castings and weld deposits. Also, good oxidation resistance. Low-cost alloy.
92	10 Mo-4 C-Bal Fe	7.90	7.41	25,000	.....	0	...	C 66	Cast	Low melting point, high-hardness alloy for abrasion-resistant castings and weld deposits. Low-cost alloy.
Hastelloy W	25 Mo-5 Cr-Bal Ni	8.90	...	135,000	90,000	35	...	C 29	Cast	Joining of dissimilar high-temperature service alloys by welding, such as turbine buckets to disks.

of steels. Intricate small parts investment cast have given excellent results in many machine and product applications where the cost of producing the article by conventional methods is high due to intricacy, and the gain in life is of significant benefit. *Fig.* 19 shows a variety of cast Tantung parts.

HAYNES ALLOYS: During the past year, the Haynes Stellite Co. has introduced two new cobalt-base alloys for high-temperature service. These alloys are known as Haynes alloys No. 25, available in all wrought forms, and No. 36, a comparable cast alloy particularly well suited to the precision investment casting process. Application of casting alloy No. 36 in a jet engine is pictured in *Fig.* 20. TABLE 21 briefly shows composition, physical and mechanical properties, form, and service applications of these two alloys, as well as of six other recent Haynes alloys designed for abrasion, corrosion and heat-resistant uses.

ILLIUM: The Illium Corp. makes two nickel-chromium corrosion-resistant alloys in cast and wrought forms with the compositions shown in TABLE 22. Illium "G" is the cast material for use where the corrosion of sulphuric, nitric, phosphoric, acetic and various mixed salt-acid solutions must be controlled. Illium "R", the wrought version of the cast Illium alloy, possesses the same corrosion resistance as the cast alloy together with the more desirable physical and mechanical properties of a wrought material.

These materials find use in two general fields: (1) Where corrosion of the equipment cannot be tolerated and (2) where total lack of contamination of the corroding media is of vital importance. An example of this latter case is the resistance to corrosion by sulphuric acid-salt solutions used as spin baths in the viscose cellulose rayon and related industries. Another example of this type is exhibited in the handling of hot aerated vinegar solutions in the food processing industry.

Combinations of corrosion and erosion have also

TABLE 22—CHEMICAL ANALYSIS OF ILLIUM ALLOYS

Alloy	Element (per cent) Ni	Cr	Mo	Cu	Fe	Mn	Si	C
Illium "G"	56.0	22.5	6.4	6.5	6.5	1.25	0.65	0.20
Illium "R"	64.0	22.0	5.0	2.5	6.0	0.30	0.15	0.05

TABLE 23—MECHANICAL PROPERTIES OF ILLIUM ALLOYS

Properties	Illium "G"	Illium "R" (Annealed)	Illium "R" (20% cold worked)
Tensile strength (psi).....	68,000	112,800	142,300
Yield strength (psi)			
0.02% offset	28,000	42,600	94,900
0.10% offset	35,300	48,100	119,400
0.20% offset	38,900	50,200	128,100
Reduction in area (%) ...	11.3	51.9	44.2
Elongation in 2 inches (%)	7.5	45.7	11.5
Proportional limit (psi) ..	21,100	32,100	66,700
Modulus of elasticity	24,300,000	31,100,000	27,900,000

been satisfactorily handled with the Illium materials. Examples of such usage are found in the pumping of sludge acids resulting from the pickling of steel, the pumping of sugar-carbon black sludges, and in valve trim used for valves handling fatty acids.

Stress versus creep rate curves for Illium at two temperatures are given in *Fig.* 21. *Fig.* 22 compares these alloys with various others regarding the stress required to produce a given creep rate. Principle mechanical properties of the Illium alloys are given in TABLE 23. Both Illium alloys are readily machinable with high-speed or carbide tools.

Cemented Carbides: Since their inception more than 25 years ago, cemented carbides have been used almost exclusively for tools in the manufacture of products. Such tools include wire drawing dies, cutting tools for lathes and similar machines, and more recently, tools for cutting, shearing, punching, metal-forming, etc.

CARBIDE COMPONENTS: One of the most significant trends of the present time is the growing use of carbides in products themselves. Depending upon particular conditions, cemented carbides may show a life of from 10 to 500 times that of the hardest steel when used at points of severe wear. The forms in which carbides are used for this purpose include bushings, bearings, gripper plates for holding parts, wear strips and guides for wire, thread, or twine.

CARBIDE EXTRUSIONS: One of the techniques of production applied to cemented carbides is extrusion, by which carbide parts are made in shapes and sizes impossible to produce by usual powder techniques. Generally, extrusion is especially suitable for the production of parts having considerable length with respect to cross-section. Such shapes as tubes, long cylinders, long strips of rectangular or square cross-section, and triangles have been successfully produced by extrusion methods, *Fig.* 23. Carbide tubing is being made in sizes ranging from 0.040-inch OD with 0.008-inch ID up to and including 0.500-inch OD with 0.300-inch ID. When properly handled, the extrusion process produces parts somewhat closer to desired size than is possible by other methods. This feature is of special value in connection with carbide tubing which, in long lengths, is difficult to finish internally.

Fig. 26—Steel powder-metal pinion produced by Powdered Metal Products Corp. of America showing variety of section thicknesses

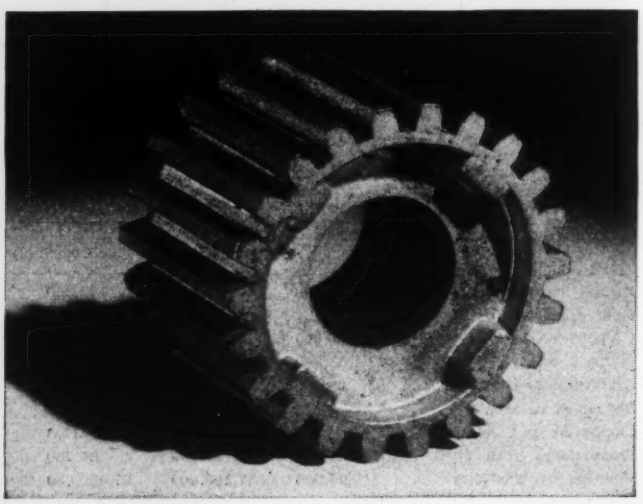


TABLE 24—PHYSICAL PROPERTIES OF PALINEY NO

	Annealed	Heat-treate
Proportional limit (psi)	89,000	145,000
Ultimate tensile strength (psi)	120,000	180,000
Elongation (% in 2")	24	9
Hardness (Brinell)	180	280
Resistivity (ohms/cmf)	210	190
Density (gm/cc)	11.9	11.9
Fusion temperature (F)	1985	1985

TABLE 25—RELATIVE PROPERTIES OF KEYONY TREATED IRON POWDER METAL

	No Treatment	Keyonyx L	Keyonyx
Wear resistance	3	2	1
Corrosion resistance	3	2	1
Strength (tension)	1	2	3
Strength (compression)	3	2	1
Hardness	3	2	1
Porosity	1	2	3
Surface quality	1	2	3

* Rating: 1=best, 3=least desirable.

KENTANIUM: Developed and produced by Kennametal Inc., Kentanium is a heat-resistant alloy material composed chiefly of titanium carbide, and a small percentage of even more refractory carbides, with nickel as the auxiliary binding metal. Neither tungsten nor cobalt is required. Three currently standard grades are available to meet the varied requirements involved in different combinations of oxidation, stress, and thermal shock. The difference consists chiefly in the percentage of auxiliary metal used.

Kentanium is available in several different physical forms, *Fig.* 24: rods, tubes, squares, and flats are extruded, and simple shapes molded, while more intricate forms are machined from pressed green slugs. When greater accuracy is demanded, the required tolerance or finish can be obtained by grinding with diamond wheels after the part is sintered. As with all cemented carbides, it cannot be subsequently heat treated, and can be worked only by grinding after sintering.

Physical properties are: Rockwell A hardness, 85.0 to 92.4; specific gravity, 5.6 to 6.0; modulus of rupture, 125,000 to 190,000 psi at room temperature, and approximately 150,000 psi at 1800 F; compressive strength at room temperature, approximately 550,000 psi; tensile strength at 2000 F, about 40,000 psi. It weighs only two-thirds as much as steel and

conventional heat-resistant alloys, has twice their resistance to deflection under load, and will resist oxidation for long exposures at 1800 F and for short periods at 4500 F. Its ability to withstand thermal shock is evidenced by the fact that specimens have been subjected to alternate heating and cooling from 1800 F to 180 F in one minute cycles for 100 hours while under a tensile stress of 12,500 psi, with no failures.

Its stress-to-rupture characteristics are noteworthy. For example, tests at 1600 F indicate a life about three times that of the best currently used alloys. This superiority increases rapidly as temperatures are raised. When its lower density is taken into account, the advantages of Kentanium for rotating parts are even more pronounced. Gas turbine blades and vanes, *Fig.* 25, and valve balls and seats are among the applications where it has shown promise of success. Kentanium blades have been run at inlet temperatures of 2200 F for as long as 110 hours, a period during which a large proportion of alloy blades failed.

Precious Metals: Among the precious metals finding application in machine components is a new alloy, Paliney No. 7, made by the J. M. Ney Company. This material is a palladium-platinum-gold-silver-copper alloy that, because of its noble metal content, has a high tarnish and corrosion resistance and is unaffected by most industrial atmospheres.

As indicated in TABLE 24, both its mechanical and electrical properties can be altered to a marked degree by heat treatment. In the annealed condition its ductility, as indicated by its 24 per cent elongation, permits extensive drawing, rolling, stamping, and forming to intricate shapes. By a simple age-hardening heat treatment, it can be made to develop high strength, hardness, and wear resistance without brittleness. The aging treatment lowers its resistivity by approximately 10 per cent.

This unique combination of properties has made the material successful in a wide variety of applications. It is being used for sliding contacts in precision potentiometers, as a resistance winding wire, as wear-resistant surfacing and in naval equipment.

POWDER METALS

Powder-Metal Process: Powder metallurgy has in recent years opened the door to a whole new field of attractive design possibilities. Answers to the combination problem of the right material for the job and its relationship to producibility are being found increasingly with powder metals. Many metals and their alloys are being formed into components by this process and, in fact, some materials are best suited to, or in certain instances amenable only to the techniques of powder metallurgy. Often, the use of powder metals speeds production, eliminates complex tooling and machining operations, and saves material.

Ferrous Powder Materials: By powder-metal techniques, impregnated iron alloys—with copper, for example—are being produced with tensile strengths to 100,000 psi. These alloys, additionally, have elongations of approximately 12 per cent and very good resistance to shock and impact. Molding combinations of sections of equal density throughout, previously one of the limting factors in the design of powder-

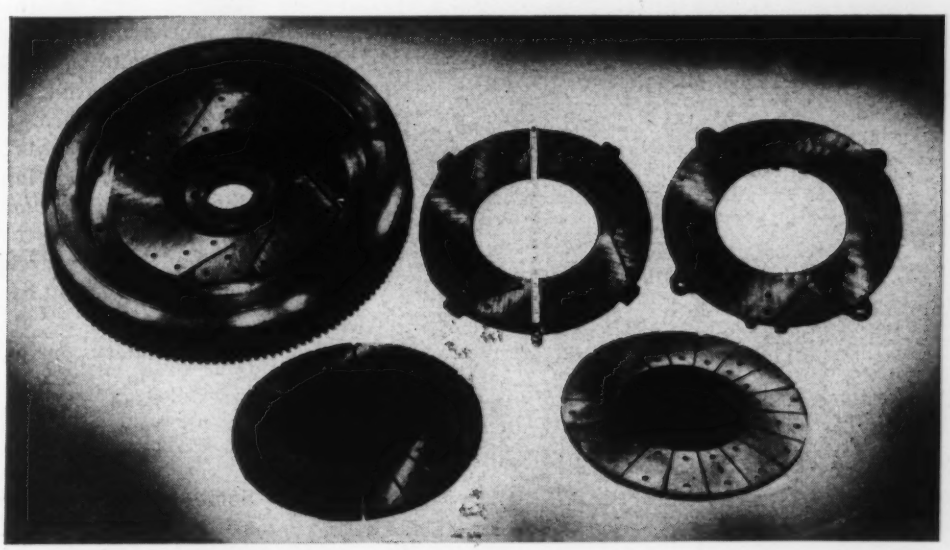


Fig. 27 — Powder-metal facings of a tractor clutch designed for friction-to-friction operation. Photo, courtesy S. K. Wellman Co.

metal parts, is now being accomplished, *Fig.* 26—as in complex shapes such as cluster gears. Also pure iron can be molded to a relatively high density, thereby imparting good electrical characteristics to powder-metal parts. Such material has found wide usage as pole pieces for meters and other magnetic components.

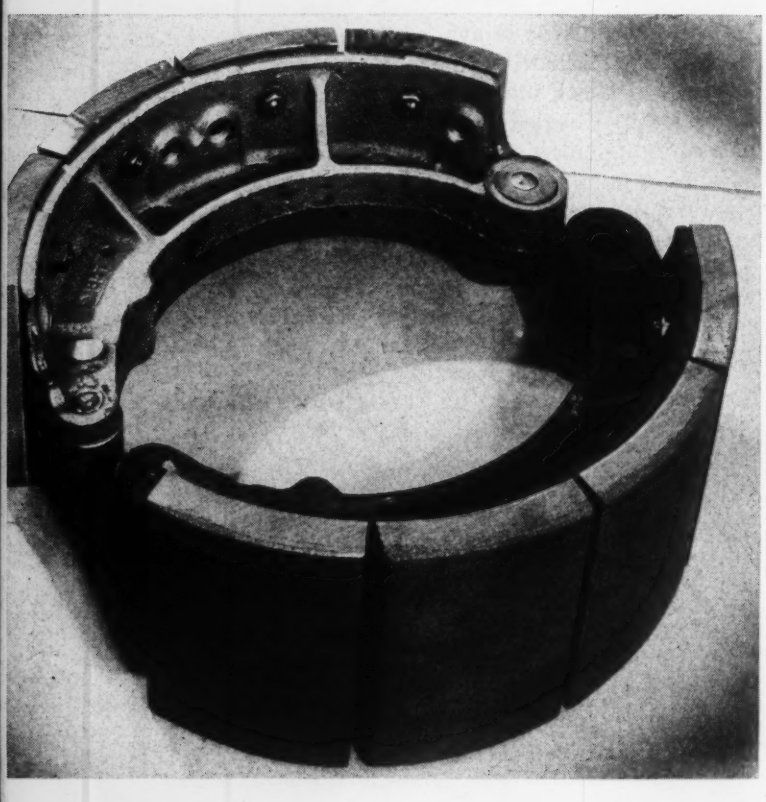
CORROSION AND WEAR RESISTANT SINTERED IRON: Corrosion and wear resistance of high-iron content sintered materials can be increased by treating them to form magnetic oxides on exposed particle areas, both on the surface and through the cross-section of the parts. Variations in this treatment, called the Keyonyx L and Keyonyx H processes by the Keystone Carbon Co., produce an even, black color entirely through a part. The cost of either treatment is small and is dependent upon the size of the piece and quantities involved. Both treatments give much the same outward appearance except for a shiny bluish tint on Keyonyx L as compared with the dusty black surface on Keyonyx H. TABLE 25 shows the relative characteristics of sintered iron so treated.

When an application requires high porosity, fine surface finish and maximum tensile strength, the original sintered material is best. For applications which do not require extremes of any of the properties, Keyonyx L performs well. As corrosion and wear resistance, compression strength, and hardness become important, Keyonyx H is recommended.

Small open-face cams, operating at high speed and light load as well as at low speed and heavy load, have worked well with the Keyonyx treatments. Machine parts operating in high humidity atmospheres are performing successfully due to the protection offered by this treatment. A typical application of Keyonyx on sintered iron is a cam for a textile winding machine formerly made from SAE 1112 bar stock. Bar stock parts were reasonably satisfactory but expensive equipment was needed for fabrication. After considerable testing, it was found that the Keyonyx-treated sintered-iron cam gave four times the life with a 20 per cent reduction in cost.

DUCTILE SINTERED IRON: Iron powder particularly suited for parts to be spun, staked and cold headed has been developed by Keystone Carbon Co. Small pieces with approximately 0.032-inch rivet diameter and ¼-inch diameter shoulder have been riveted into cold-rolled steel plates 1/16-inch thick. A load applied to the piece ½-inch from the plate sufficient to bend the plate does not loosen the rivet or break the piece. In the standard modulus of rupture tests, these pieces show a pronounced deflection before failure in comparison to most sintered materials, which break with practically no deflection.

Fig. 28—Heavy-duty truck brake shoes showing powder-metal friction facings. Photo, courtesy S. K. Wellman Co.



Friction Materials: Another rapidly growing area of powder metal usage is friction materals. Powder-metal friction material is composed of a sintered mixture of metal and nonmetal powders developed to achieve desirable friction results. The most commonly used powders are copper, iron, tin, lead, graphite and silica.

Sintered metal friction elements are processed in much the same fashion as other powder-metal products. The dry powders of the constituent elements are mixed and blended in correct proportion and then molded at room temperature under high pressures and subsequently sintered. Primarily, powder-metal friction material is justified on its performance rather than its first cost. Its first cost is generally higher than that of competing friction materials such as molded or woven asbestos. The size range of friction elements is probably greater than that generally offered in other fields of powder metallurgy. Friction elements range from a few ounces to 140 pounds in weight, with friction facings of diameters less than 1 to 72 inches.

Another important factor in the manufacture of powder-metal friction material is chemical composition. Chemical composition of friction powder metals can be related to wear, coefficient of friction, operating temperatures, and other factors. A typical composition would be:

Carbon	6.0%
Silicon dioxide	4.4%
Tin	5.4%
Lead	8.7%
Iron	7.4%
Copper	68.1%

Some compositions employ as many as eight constituents and as high as 10½ per cent by weight or

35.79 per cent by volume of nonmetallics. The amount of nonmetallics is a function of green strength and sintered strength; for example, metal powder bearings average 3 per cent by weight of nonmetallics while other parts such as powder-iron gears average about 1 per cent.

Typical friction parts made from powder metal are shown in *Figs.* 27 and 28. The trend toward powder metal to powder metal braking surfaces is typified in *Fig.* 27, a friction-to-friction installation on a tractor master clutch. This is a double-plate assembly with an additional center plate, faced with a powder-metal wearing surface, mounted between the two clutch plates. *Fig.* 28 shows truck brake shoes mounted with powder metal blocks. Studs are welded directly to the backs of the blocks for mounting to the shoes. The space between the blocks is beneficial for scavenging both wear and foreign dirt particles and for relieving the lining and shoe of excessive thermal stresses.

NONMETALLICS

CERAMICS AND REFRACTORY MATERIALS

Ceramics Compositions: As an engineering material requiring raw ingredients that are abundant, widely distributed and of relatively low cost, ceramics merit increasing attention from design engineers. Most important, the unique high-temperature characteristics of certain ceramics are making possible advanced designs which could not have been achieved with metals alone. Chief properties for which ceramics are specially suited in engineering applications are refractoriness, hardness, and dielectric characteristics.

Recent developments have produced ceramics with higher strength, higher heat resistance, better electrical properties, and increased resistance to wear. No one composition combines all these advantages. To attain these favorable qualities, a series of compositions have been improved or developed. Each of the series is outstanding in one or more of the desirable characteristics.

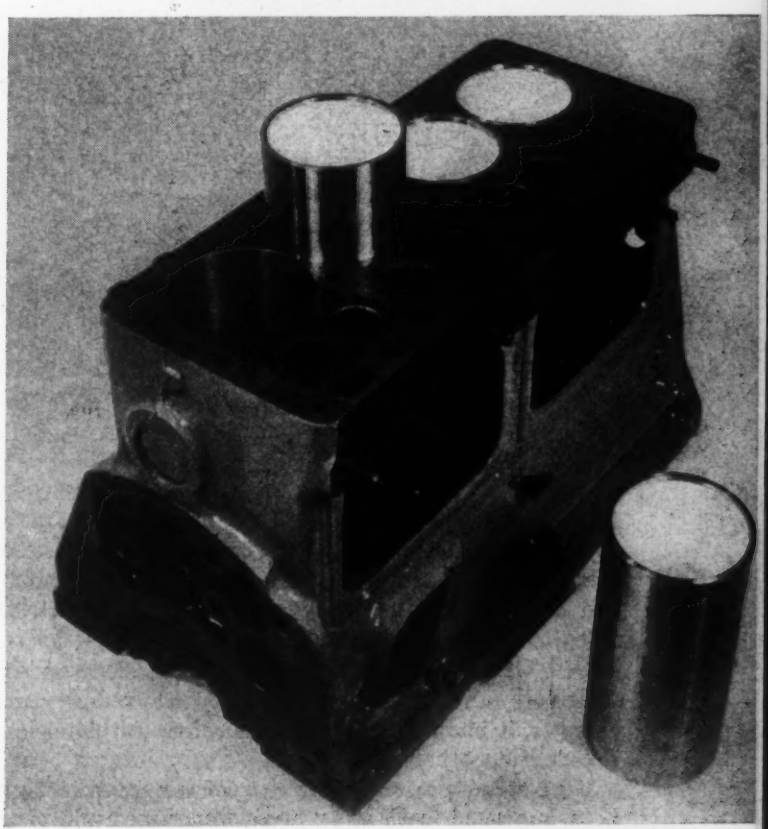
High-strength compositions of alumina and zircon have been improved. Notable among the compositions which have high strength is AlSiMag 491, produced by the American Lava Corp. This ceramic has a flexural strength of 45,000 psi and a hardness of 9 on the Mohs scale. It is a fine-texture ceramic, resistant to abrasion, chipping and corrosion.

These characteristics have resulted in its wide use as extrusion nozzles for such things as other ceramics, pencil leads, battery carbons, and soft wires. It has, on many applications, proved to be superior to tungsten-carbide dies. It can be furnished to close tolerances, has long life and is low in cost. The material is rough machined in the unfired state and brought to final dimension after firing at relatively low cost. AlSiMag 491 is also widely used for thread guides, wire recorder guides, etc.

METALLIZED CERAMICS: Metals are being successfully applied to ceramics by several methods, including deposition by evaporation of metal in vacuum. Another method is to paint a base coat, dry, fire and build to desired metal thickness by electrochemical deposition. Successful metallizing requires matching expansions between the metals and the ceramics.

JOINING CERAMICS: High-strength ceramics have

Fig. 29—Waukesha engine block showing sintered Alundum cylinder liners. Metal sleeve is used to support the thin ceramic liner



been developed which can be joined by riveting. More recently, mechanically fitted or pressed combinations of metals and high-strength ceramics have been successfully produced. The method requires extreme dimensional accuracy in both ceramic and metal parts.

CERAMIC PARTS MANUFACTURE: The technique of grinding ceramics after they have been fired has been materially advanced. Firing converts these ceramics to very hard materials, most of which are 8 or 9 on the Mohs scale. However, on critical dimensions which lend themselves to grinding, AlSiMag ceramics are being produced with dimensional accuracy comparable to precision metal parts. Several of the compositions are more wear resistant than steel and, in suitable applications, can be manufactured to close tolerances at low cost.

Grinding is most practical on flat and round surfaces. Equipment is available to grind flats up to 50 sq in., rods up to 10 inches diameter and holes as small as 3/16-inch. By a combination of grinding and lapping it is possible to achieve flatness measurable in light bands. Since the material is wear resistant, is not subject to rust or corrosion, and is relatively unaffected by chemicals or temperature changes, it has found wide use as reference plates and in numerous other applications.

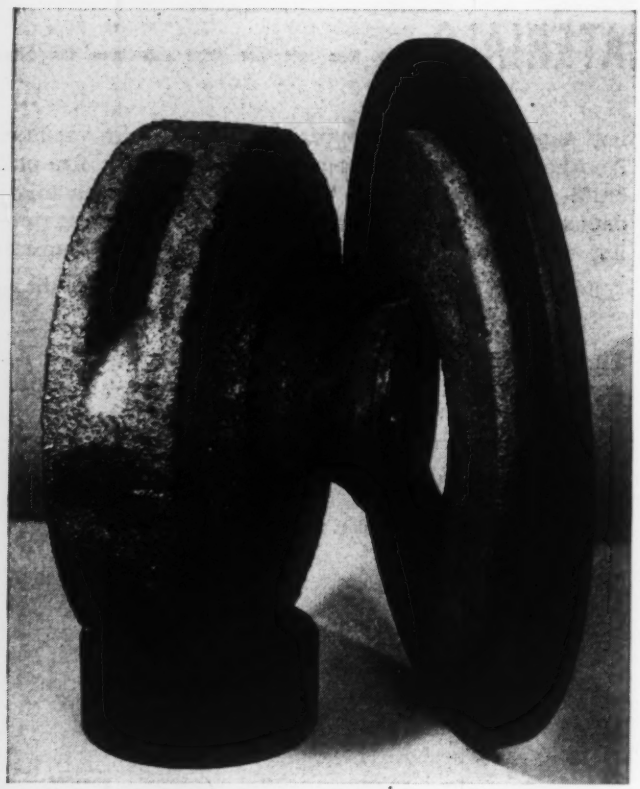


Fig. 30—Crystolon impeller and follower plate for slurry pump

High-speed pressing and extrusion processes have been improved, both as to production speed and quality of product. An extension of quality control work has resulted in marked improvement in product quality as well as lower costs and more dependable deliveries.

Good progress has been made on controlled finishes of ceramics. In some applications a very smooth finish is desired. Other requirements call for finishes from eggshell to satin. Techniques for polishing to the desired degree have made encouraging progress. The development of moisture repellent treatments with silicones has also been favorable.

ALUMINUM OXIDE PARTS: Cold-pressed sintered Alundum (Norton Co.) cylinder liners have been used in internal combustion engines, *Fig.* 29. Inserted in a metal sleeve, the ceramic liner showed no signs of wear after conditions of operation that severely wear cast iron cylinders. The material has also been used for mechanical seals and for check valves (balls and seats). In the cold-pressed form, Alundum has specific gravity 3.7, modulus of rupture 30,000 psi and compressive strength 300,000 psi. Values are slightly higher for hot-pressed forms.

STABILIZED ZIRCONIA: Having exceptionally high melting point (4700 F), low thermal conductivity, and high chemical stability, fused stabilized zirconia (Norton Co.) is finding application in jet and rocket engine parts as well as for thermal insulation in high-frequency induction and resistor wound furnaces. Zirconia becomes a conductor above 2700 F and has been used to some extent as the heating element in electric furnaces.

BORON CARBIDE: Claimed to be the hardest material made by man, Norton boron carbide (Norbide) is being used for mechanical seals and for nozzles in sand-blasting and shot-peening equipment. Experiments are under way on application to sleeve bearings. With an ultimate compressive strength of 300,000 psi, hardness between that of silicon carbide and diamond, and specific gravity only 2.52 as molded Norbide, the material is highly resistant to corrosion and high temperature.

SILICON CARBIDE: A good, readily available material for such exacting applications as rocket-motors is silicon carbide, SiC. A bonded composition known as Niafrax A (The Carborundum Co.) has been successfully applied as combustion chamber liners and exhaust nozzles in liquid propellant motors and as nozzle inserts in solid propellant motors. The material does not soften or melt when heated and the bond does not decompose below 3400 F. Modulus of rupture is 5000 to 7000 psi at 2460 F, specific gravity is 2.7 to 2.8, and thermal expansion is 3.7×10^{-6} inches per inch per deg F. Because there is little change in size during firing, close tolerances can be held, making it usually unnecessary to machine or otherwise finish parts.

Bonded Crystolon (Norton Co.) has been developed for wear-resistant machine parts such as mechanical seals and the impeller and follower plate for a slurry pump, *Fig.* 30. Wear life of this im-

peller is many times that of the metallic impeller which it replaced. In this form Crystolon has specific gravity 2.73, modulus of rupture 15,000 psi, and compressive strength 100,000 psi.

MAGNETIC FERRITES: A relatively new development, with rapidly expanding uses, is the application of magnetic ferrites or Ferramics (General Ceramics and Steatite Corp.) in the manufacture of electronic and electrical parts.

By virtue of their extremely low loss characteristics and higher permeabilities and saturation flux densities, Ferramics are filling the need long existent in the family of magnetization curves falling in between the nominal values previously possible with powdered iron materials and soft magnetic steels.

Ferramics can be extruded and pressed in various shapes with comparatively low initial tool cost. The material is dimensionally stable, and contains no organic binder. Many of the new applications for Ferramics include high-frequency transformer cores, toroidal coil cores, induction heating field concentrating slugs and shield rings, magnetic recording drums, ignition coil cores, computer components, electronic components, and miniaturization of military radio equipment.

SYNTHETIC CRYSTALS: Possessing unique mechanical optical, chemical and dielectric properties, synthetic crystals (Linde Air Products Co.) are finding increasing uses in machine parts, particularly where exceptional wear resistance is required. With compressive strength 300,000 psi and modulus of rupture 65,000 to 100,000 psi, synthetic sapphire is used for bearings in watches and instruments; guides for textiles, wire, tape and film; dies for drawing and extruding soft metal and plastics; orifices for oil burners and diesel injectors; and balls for bearings and check valves. Other, less hard, synthetic crystals which are being used for parts are spinel, titania, calcium tungstate and cadmium tungstate.

Metal-ceramic Compositions: Sintered combinations of ceramic and metallic ingredients known as ceramal or Metamic (Haynes Stellite Div., Union Carbide and Carbon Corp.) materials have properties possessed by neither ceramics nor metals alone. These include exceptional strength and resistance to oxidation and high temperature. The metal constituent adds thermal conductivity and shock resistance. The ceramic constituent adds resistance to deformation under stress at high temperautre—1800 to 2500 F—plus resistance to oxidation. A typical composition, Metamic LT-1, has a tensile strength of 17,500 psi at 1800 F with virtually no elongation or reduction of area. Applications include flame jet nozzles, gears and threaded fasteners for high temperature.

Ceramic Coatings: Although metallic alloys and carbides used in gas turbines and rocket engines retain much of their mechanical strength at elevated temperatures, they are subject to oxidation which in a matter of hours can completely destroy a blade or nozzle. Intensive research is proceeding on ceramic coatings which protect the surfaces of such functional parts from the oxidizing gases. An example of a successful combination is reported by three National Bureau of Standards workers in *NACA Technical Note* 2329. The base material is a sintered combination containing 80 per cent titanium carbide and 20 per cent cobalt (Kentanium), which has a tensile strength of 31,800 psi at 1800 F. The protective coating is a ceramic containing 80 per cent chromium powder and 20 per cent glass. Tests showed the coating to afford complete protection in air at 1800 F, with no oxidation after 200 hours. Also, the coating had sufficient ductility to "creep" with the base material at elevated temperatures.

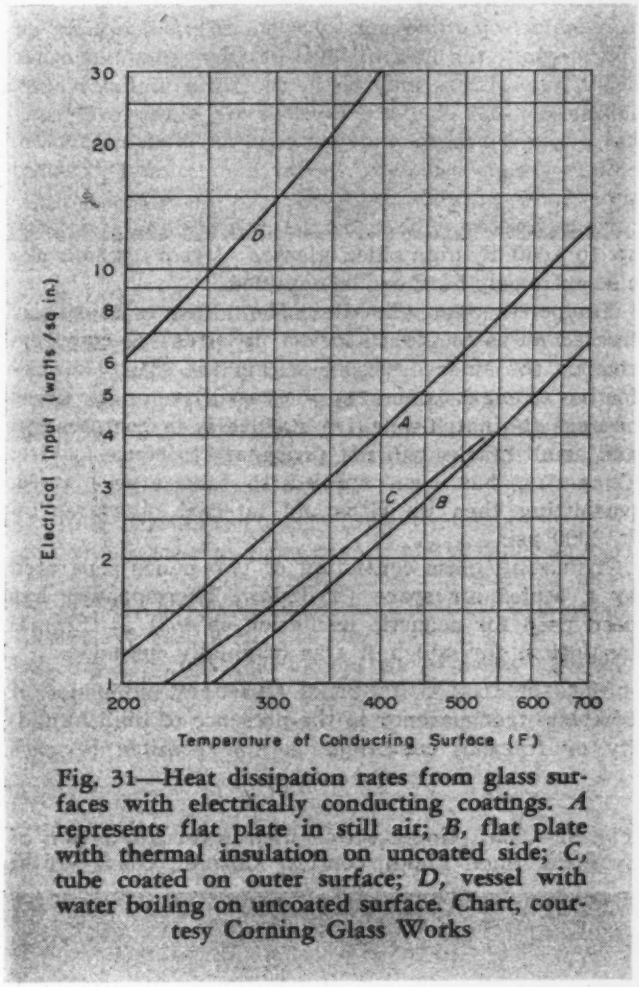


Fig. 31—Heat dissipation rates from glass surfaces with electrically conducting coatings. *A* represents flat plate in still air; *B*, flat plate with thermal insulation on uncoated side; *C*, tube coated on outer surface; *D*, vessel with water boiling on uncoated surface. Chart, courtesy Corning Glass Works

Glass: Glass in industrial equipment generally is employed to take advantage of one or more of the unique optical, thermal, electrical, and chemical properties of the material. Development of glass compositions resistant to thermal shock, of tempering to increase strength, and of laminating to prevent shat-

tering and to provide thermal insulation, have greatly increased the potential value of glass as an engineering material. The resulting product is a far cry from the comparatively fragile window glass and tableware to which we have become accustomed. More recently, improved techniques in applying microthin coatings have extended the properties of glass optically, thermally, and electrically. The following summary reviews briefly the noteworthy advances of possible significance to design engineers.

OBSERVATION WINDOWS: The transparency, hardness, and corrosion resistance of glass are an ideal combination for all types of windows through which a machine operator can observe the functioning of mechanisms, the flow or level of lubricants and other fluids, etc. Glass may be in the form of flat plates, tubes, or other shapes. Borosilicate glasses (Pyrex) have high strength and low coefficient of expansion, making them resistant to mechanical and thermal shock and suitable for application in high-temperature equipment. For unusually high temperatures, up to 1650 F, high-silica glasses (Vycor) which are also extremely hard can be obtained.

Tempered glass (Tuf-flex, Herculite) is thermally treated so as to induce locked up stresses—compressive on the surface, tensile within the glass. The effective strength is thereby increased five or six times because the notch-sensitive surface is in compression and small cracks will not propagate to cause failure. Tempering has been applied to lubricator glasses, permitting then to withstand internal pressures up to 2000 psi.

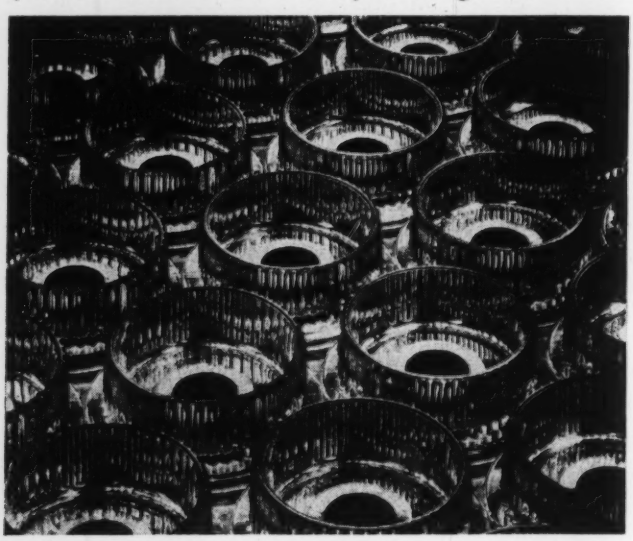
Insulating glass consisting of two panes separated by a sealed air space (Twindow, Thermopane) has been used for acoustic insulation as well as thermal insulation, for which it was originally intended.

ELECTRICALLY CONDUCTING GLASS: Maintenance of complete transparency in the presence of high humidity or freezing conditions is now possible through the development of thin transparent metal oxide coatings which can conduct electricity (Electrapane). Only 15 to 20 microinches thick, these films are as durable as the glass itself and retain their electrical stability on a-c currents at temperatures up to 660 F for life periods of 2000 to 5000 hours. The film is usually applied on the inside of laminated (safety) glass, hence the permissible temperature may be limited to that which the polyvinyl butyral plastic lamination can withstand (150 F). Relationship between heat input and temperature of the conducting surface for various conditions (E-C Radiant Panels) is shown in *Fig.* 31. Windows of this material have been applied to all types of vehicles and military equipment exposed to arctic climates, as well as to industrial equipment in humid environments. Electrically conducting glass has found application as low-temperature (660 F) radiant heaters. Because the entire surface is effective, heat emission over large areas is uniform, a useful characteristic in drying lacquered surfaces, synthetic sheets, and similar materials in processing.

A unique characteristic of these transparent metallic oxide films is that the radiant emission and reflectance is selective and different from that of the glass. Transmission is high in the visible range of wave lengths and the reflectance low—between 5 and 10 per cent. At 660 F, reflectance is high, on the order of 65 per cent, so that the uncoated side of the glass is used to radiate the heat energy. These characteristics of good visible light transmission and high reflectance of heat are useful for protecting personnel exposed to high temperatures in industry. By variation of the composition of the film, transmission in the visible range can be reduced greatly so that the interior of a high-temperature furnace can be viewed comfortably.

Other applications for electrically conducting glass include electrostatic dissipation and radio-frequency shielding.

Fig. 32—Glass Godet wheels used in the production of synthetic fiber. Photo, courtesy Corning Glass Works



OPTICAL FILTERS: Design of many new and improved optical and electronic instruments and devices, including industrial color television, has been made possible through the development of dichroic mirrors or filters (Liberty Hi-Efficiency). Made by vacuum coating commercial plate glass or optically ground and polished glass, these filters divide incident light into reflected and transmitted complementary colored beams with virtually no absorption. Electrical resistance of 20 to 40 ohms per square foot can be introduced, permitting elimination of static electricity and allowing introduction of space charges. This property of conductivity can be used in the same manner as in regular electrically conducting glass—for example, to heat the material.

MACHINE PARTS: Sanitary and corrosion-resistant properties of glass are particularly useful in food processing, pharmaceutical and chemical applications. Glass piping, containers, valves, and pumps are being widely used in conjunction with parts of nickel or stainless-steel alloys. These applications suggest glass

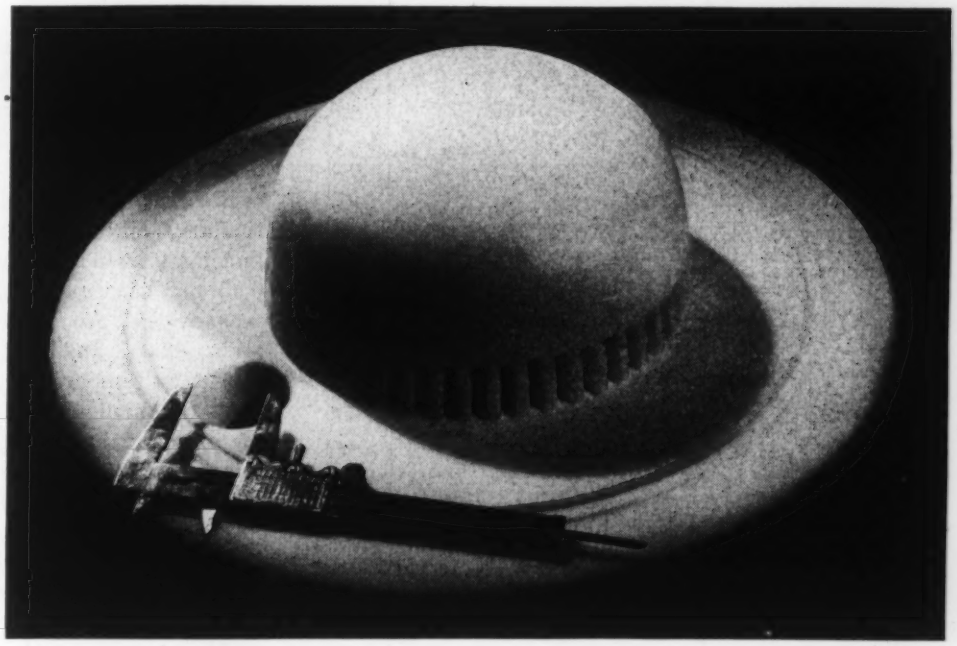


Fig. 33—Glass plate and bubble cap for distillation column produced by a ceramic process without use of steel molds

as a possible alternate for more highly critical materials in certain types of service.

Rollers and pulleys of glass are being used in the continuous processing of materials in filament or sheet form. An example is the Godet wheel, *Fig.* 32, where acid resistance and accuracy of perimeter are essential in the production of synthetic fiber. Glass rollers are used in producing plastic sheet and in the coating of copper wire with insulating enamel, because of resistance to acids.

Economical production of complex glass parts weighing ¼ to 50 pounds in limited quantities has been made possible recently by the adoption of ceramic techniques of fabrication (Corning Multiform), which do not require expensive molds. The resulting parts are white and translucent rather than transparent but are resistant to chemical action and to thermal and mechanical shock. Shapes need not be symmetrical, single or multiple holes can be provided, and tolerances may be held as close as ±2 per cent or 0.010-inch, whichever is greater. An example is the plate with an integral bubble cap for a distillation column, shown in *Fig.* 33.

PHOTOSENSITIVE GLASS: New techniques in applying photosensitive glass have made possible improved markings for illuminated scales and dials in instruments. When exposed to ultraviolet light and suitably processed, photosensitive glass can be given color or opacity through the section so exposed, the other parts remaining clear and transparent. Sharper definition of fine markings, with permanent accuracy, can be produced by this method.

PLASTICS

Recent Trends: Over the last decade, plastics have taken amazing strides in advancing to their current significant roles as engineering materials. Yet there is still a tendency on the part of many to view plastics with skepticism. This attitude, of course, is carried over from that earlier period when plastics often were improperly applied—when advantage was taken of low-cost material and methods without adequate concern for serviceability of the end product. Plastics producers have come far in developing new compounds which, in the main, preserve these initial advantages but which also give properties that establish plastics as outstanding materials for many applications.

Improved high-temperature properties, resistance to a wider variety of corrosive agents, greater strength under impact—these and other enhanced physical properties in a multitude of combinations mark recent plastic developments. Hence, plastics today are finding increasing successful applications along with metallics and other nonmetallics in an endless list of ever-broadening design requirements. In fact, just as other older materials are still best suited to certain designs, so are plastics proving to be the best or only feasible materials for other applications. Some idea of the range of properties available in plastics today can be gained from TABLE 26 which presents pertinent data for plastic families in brief form.

How plastics best fit into the current conservation program often is not clearly understood. The thought that plastics are "substitute" materials is not valid

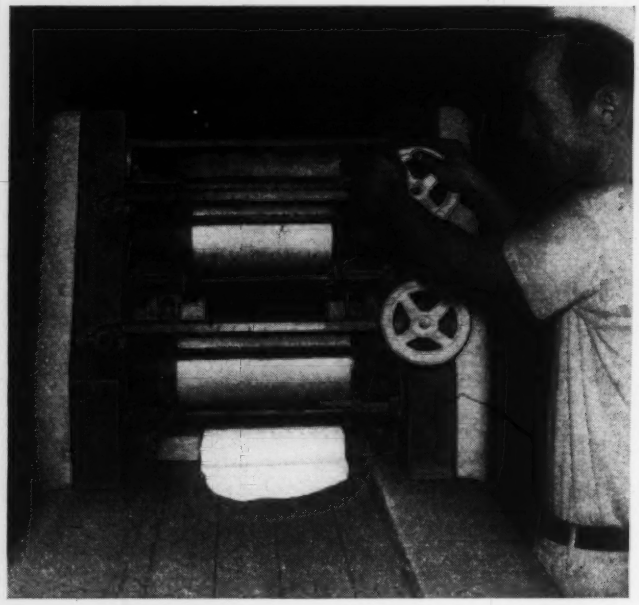


Fig. 34—Bread-molding machine produced by Sticklber & Sons Inc., showing rolls which are covered with a Teflon layer to prevent dough from sticking

generally. Many plastics are in short supply because of both the increased demand for them and their utilization of raw ingredients that are also required for other materials now essential. In the sound appraisal that includes all factors in material selection, plastics must be considered on a par with other possible materials—whether for an initial design or for an alternate-material redesign.

High-Temperature Resistant Plastics: The service range of plastics has been greatly extended by new compounds which possess exceptional high-temperature properties. These materials, such as Teflon, Kel-F, and Plaskon Alkyds, have been available in basic forms for some time. But their potential applications are only beginning to be realized. Variations in form or composition and new-found engineering applications are constantly being developed.

TEFLON: DuPont's Teflon is a heavy-duty plastic finding great usefulness as electrical insulation at high frequencies and elevated temperatures, or as a gasket and packing material in the chemical processing industry. Teflon (tetrafluoroethylene) is supplied in the standard shapes of sheets, rods, tubes, and tape; as molding powder, both shredded and granular; and in stable aqueous dispersions. Teflon can also be obtained in lacquers and enamels.

Complex articles are formed by machining the standard shapes. Teflon cannot as yet be molded by the conventional techniques used with other plastics, because it does not melt and flow. It can be molded into simple shapes, however, by an adaptation of the compression molding process.

As a suspensoid, Teflon can be applied to surfaces, by dipping or by spraying the suspensoid onto the surface being coated, and then drying and fusing at elevated temperatures. Teflon tape can be handled easily because of its flexibility, toughness, and ability to stretch, which makes it practical to tape over sharp bends. Tape and sheet stock can also be die-drawn into parts with simple curvatures.

Electrical properties of Teflon are outstanding, particularly since they remain so at high frequencies and high temperatures. Its power factor is less than 0.05 per cent even at frequencies as high as 30,000 megacycles. And its power factor, low dielectric constant (2.0), and high dielectric strength are unaffected by temperatures up to at least 400 F.

Its mechanical strength is high over a wide range of temperatures. Its impact strength is high at temperatures even below −90 F, and it is capable of continuous service at 500 F.

Teflon has the highest degree of chemical inertness of any commercial plastic, being attacked only by molten alkali metals and by fluorine gas at elevated temperatures and pressures. It can be boiled in aqua regia, hydrofluoric acid, sulfuric acid, or nitric acid with no change in weight or properties. It has zero water absorption, and is unaffected by outdoor weathering.

Another important property of Teflon is that nothing sticks fast to it. For this reason it is being used in many parts of manufacturing equipment where a nonsticking surface is needed, such as jaws of heat-sealing machines, valve seats, seals, and on conveyors and rolls handling sticky materials, *Fig.* 34.

KEL-F: Developed by the M. W. Kellogg Co., Kel-F is a new stable, high-temperature, nonflammable thermoplastic. It has high resistance to chemical action. No effect has been observed after prolonged exposure to concentrated sulfuric, hydrofluoric and hydrochloric acids, to strong caustic, to fuming nitric acid, aqua regia and other vigorous oxidizing materials. It is equally resistant to most organic solvents but is slightly swelled and plasticized by highly halogenated materials and some aromatics.

Kel-F plastic (trifluorochloroethylene) has satisfactory properties over a wide temperature range—from a low of −320 F (liquid nitrogen) to a high of 390 F. It has high resistance to electricity and is a poor conductor of heat. Although the electrical properties of Kel-F plastic are superior to most plastics, the inclusion of a chlorine atom does introduce a dipole which has some effect on the electrical properties in the very high frequency range. However, the dielectric constant is in the range of the best available materials. Another unusual property of Kel-F plastic is its exceptional resistance to wetting by water. It also is unaffected by high humidity or tropical exposure. These properties are inherent with the material and not due to processing.

Kel-F plastic can be made transparent or translucent to visible light as desired. It is also sufficiently transparent to longer wave lengths for use as a window material in the infrared region.

The fabricating characteristics of Kel-F plastic are

good. It may be fabricated by conventional machinery that is designed to operate in the range of 480 to 650 F. It may be compression, transfer injection or extrusion molded. It has been fabricated in the form of sheets, films, tubing, rod, shaped pieces or as insulation on wire. It can be readily punched and drilled or otherwise machined to close tolerances.

Kel-F is amenable to heat treatment. Just as the properties of steel may be widely varied by tempering or heat treatment, so may the properties of this new plastic be similarly varied over a considerable range. Consequently, Kel-F plastic may be made relatively soft and resilient, resembling a plasticized material or harder and less yielding without expensive processing. A significant feature of such treatment is that no sacrifice of any of the stability characteristics of the plastic is made. No plasticizing agent is required. One of the most noteworthy properties of Kel-F plastic, in addition to its chemical inertness, is its high impact strength at low and high temperatures and its resistance to thermal shock.

Kel-F is finding use as insulation and wire coating and condenser foil for applications under corrosive conditions at extended temperature ranges in motors, transformers, control instruments, signal devices, radio, radar, etc.

In the chemical industry and related fields it is suited for valve seats and valve packing; as pump packing and diaphragms, chemical pipe, tubing, and gaskets; as protective coatings on chemical processing equipment and containers; etc.

Dispersions of Kel-F are also now available. These dispersions provide for the application of Kel-F to materials and equipment not amenable to coating by conventional plastic molding. After the thinner evaporates, the dry particle coating is white. After fusion, the fused protective film is transparent to semitransparent, depending on film thickness. The characteristic properties of Kel-F films, produced by coating from dispersions followed by fusion, have been found to be comparable to those of same protective coatings applied by pressing, extrusion or compression molding.

NYLON: Although nylon, developed by DuPont, is not a new composition, it is finding many new uses as an engineering material. Several nylon (polyamide) molding powders are available for injection molding, extrusion, and wire-coating. These are actually different, though related, chemical compositions whose physical properties differ in degree of heat-resistance, flexibility, chemical resistance, and fluidity at the molding temperature.

Some types of nylon are form-stable above 400 F. However, they are not usually recommended for continuous operation at temperatures over 250 F. Nylons are tough, even at low temperatures, and are resistant to both abrasion and impact.

The most widely used type, FM-10001, has good resistance to most chemicals, except concentrated mineral acids and phenols. In addition, it has excellent bearing characteristics. Its high fluidity at molding temperatures and strength permit the molding of thin sections and around delicate inserts. In moving parts, nylon provides quiet operation either with no lubrication or with less than that required by other materials. The greatest single nondefense use of nylon plastic has been in machine parts, generally in those parts subjected to friction, such as bearings, gears, and cams. Nylon has been adopted for gears and blades in food mixers; gears and connecting rods in electric shavers; rollers and conveyors in a dishwashing machine; gears for movie cameras and projectors; heavy-duty sleeve bearings for circuit breakers; etc.

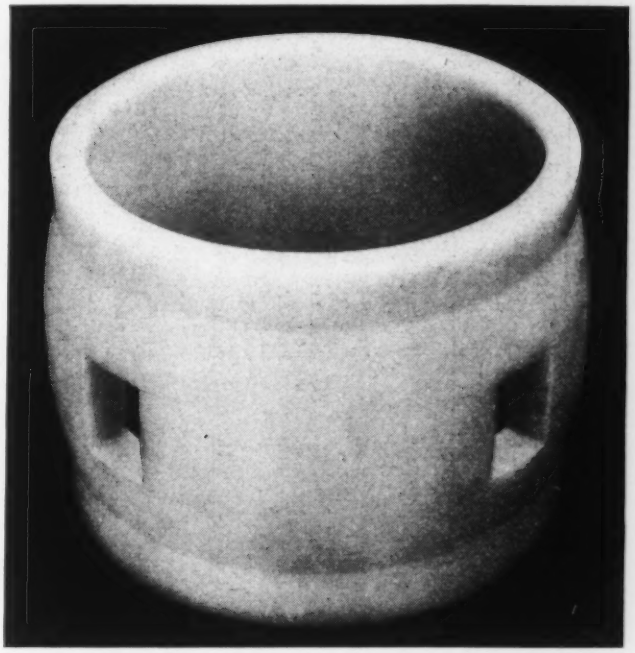


Fig. 35—Large bushing machined from cast nylon used as a bearing in a food handling device. Lubrication of bearing metal-chip contamination were eliminated. Photo, courtesy Polymer Corp. of America

Recently large-diameter nylon bushings from 1¼ to 8⅜-inch OD have been made. Bushings in these large sizes have been used for thrust bearings where normal lubrication cannot be tolerated or where an abrasive condition would abuse metals or other materials. A specific application is shown in *Fig.* 35. Another example is the nylon bearing cage shown in *Fig.* 36. This improved pinion assembly, used in the transmission of the Bell helicopter, has increased the interval between necessary inspections of the transmission from 25 flight hours to well beyond the maximum required by CAA.

Nylon is also available in standard forms such as rod, strip, and tubing. Strip can be economically blanked into precision parts such as small timing gears, flap valves, gaskets, tuning condensers and other small parts. Good machining properties of nylon lend it readily to close-tolerance work. One intricate piece machined from nylon rod contains 128

TABLE 26—APPLICATIONS AND PHYSICAL CHARACTERISTICS OF TYPICAL PLASTICS

Type	Filler	Colors	Tensile Strength (psi)	Flexural Strength (psi)	Water Absorption (% 48 hr)	Heat Resistance (Cont. F)	Specific Gravity	Shrinkage (in./in.)	Applications to Machines
Thermosetting Plastics									
Phenolic	None	Amber	7,000	12,500	0.02	248	1.27	0.012	Sterilizable parts, milking machine parts, hard jewel bearings.
Phenolic	Woodflour	Most colors	7,500	11,000	0.8	248	1.38	0.007	General-purpose, housings, etc.
Phenolic	Woodflour and graphite	Gun metal	6,000	8,000	0.8	248	1.39	0.007	Bearings, cams, slides, caster wheels, etc., for reduced friction.
Phenolic	Long fiber asbestos	Black, brown, natural	5,000	10,000	0.06	300	1.90	0.001	Best for heat resistance, low moisture absorption, low expansion, stability.
Phenolic	Asbestos and graphite	Gun metal	5,000	8,000	0.06	300	1.82	0.003	Bearings, slides, gears, valves, cams, etc., stability, resistance to wear.
Phenolic	Fabric, short fiber	Natural, black, red, brown	6,200	10,500	1.0	248	1.39	0.002	Medium impact, good flow for complex sections. Agitators, housings, etc.
Phenolic	Fabric, medium fiber	Black, brown, red	6,300	10,000	1.0	248	1.40	0.002	High impact for bulky sections.
Phenolic	Chopped cord	Black	6,200	11,000	1.4	248	1.35	0.003	Highest impact, not good for complex sections.
Phenolic	Fabric and graphite	Gun metal	6,000	8,000	1.0	248	1.45	0.004	Cams, bearings, slides, gears, etc., for high impact, low friction.
Phenolic	Cotton flock & graphite	Gun metal	6,000	9,500	1.0	248	1.41	0.002	Bearings, cams, gears, slides, etc., for medium impact, low friction.
Urea	Cellulose	All	6,000 to 13,000	10,000 to 16,000	1.5	170 to 245	1.48	0.006 to 0.011	Cabinets, housings, ignition parts.
Melamine	Fabric	Natural, white black and colors	9,500 to 10,500	12,000 to 15,000	0.5	250	1.49	0.004	Good shock resistance. For nozzles, carburetor housings, medical equipment parts.
Melamine	Cellulose	All	8,000 to 13,000	10,000 to 16,000	1.0	210	1.45	0.008 to 0.015	For inserts, aircraft electrical connectors, switches, instrument housings.
Cold Mold	Nonrefractory asbestos	Black, brown	.....	5,500	3.0	370	2.00	0.010 to 0.025	Best cold mold for appearance. For wiring parts, small gears, handles, heat insulators, heavy-duty wheels, etc.
Cold Mold	Nonrefractory asbestos	Gray	.....	5,000	0.4	750	2.10	0.000 to 0.010	For parts requiring maximum heat resistance, switch parts, rheostat parts, etc.
Cold Mold	Refractory asbestos	Gray	.....	4,000	6.0	750	2.10	0.005 to 0.015	For parts subject to high-power arcing.
Teflon (Du Pont)	.....	Waxlike white or gray	4,500	2,000	0.00	400	2.10	....	Good flexibility at low temperatures, stability under heat, for gaskets, packings, diaphragms and valve seats, etc. attacked only by alkali metals.
Alkyd (Plaskon)	Mineral	Brown	3,000 to 4,000	8,000 to 10,000	0.11 to 0.16	400	2.2	0.004 to 0.007	For mechanical and electrical parts requiring high heat or arc-resistance and good dimensional stability.

Kel-F (M. W. Kellogg)	.....	Waxlike white or colors	9,400	.....	0.00	400	2.1	...	Satisfactory for temperatures to —320 F, high stability, extreme chemical resistance, for diaphragms, gaskets, seals, valve seats.
Hard Rubber (Ace)	.....	Black, yellow-brown, red-brown	2,000 to 9,700	2,818 to 16,600	0.04 to 0.30	300 to 102	1.15 to 1.95	0.020	Outstanding chemical and corrosion resistance, good electrical qualities, for gears, water-resistant parts, wheels, electrical parts, process equipment parts.
Mycalex (G.E.)	Mineral	Gray	6,000 to 16,000	12,500 to 22,000	0.001 to 0.03	482 to 662	2.64 to 3.70	0.001	General-purpose material for parts requiring exceptional high-frequency characteristics, heat resistance, low moisture absorption, or arc resistance.
Enrup (U.S. Rubber)	.....	.....	4,200	.....	0.6	180 to 250	1.3	....	Outstanding toughness resistance to abrasion, oils, solvents, acids, mild alkalis, exceptional impact strength. For pump parts, valve seats, gears, bearings, impellers, distributor caps.
Thermoplastics									
Cellulose-acetate	.....	All	5,000 to 11,000	4,000 to 8,000	3.0	140 to 250	1.28 to 1.32	0.002 to 0.003	General-purpose for motor housings, etc.
Cellulose-acetate-butyrate	.....	All	2,500 to 7,500	2,800 to 13,000	1.5	136 to 200	1.15 to 1.22	0.002 to 0.003	General-purpose, for fuel lines, handles, rollers, refrigerator and vacuum sweeper parts.
Ethyl cellulose	.....	All	6,000 to 9,000	4,000 to 12,000	1.4	180 to 140	1.12 to 1.15	0.004 to 0.007	Parts with good strength at low temperatures, bobbins, camera and clock cases, dairy equipment parts.
Polystyrene	.....	All	5,000 to 9,000	8,000 to 19,000	0.05	158 to 175	1.06	0.002 to 0.008	Good stability, low moisture absorption, for battery cases, housings, refrigerator parts.
Vinylidene chloride	.....	Translucent, amber & opaque	6,000	16,000	0.1	160	1.70	0.010	For chemical equipment parts, valve seats, textile machinery parts, fuel pump parts, pistons, etc.
Methyl Methacrylate	.....	All	4,000 to 10,000	10,000 to 19,000	0.5	140 to 190	1.18	0.003 to 0.006	Transparency and stability excellent, for windows, dials, optical systems.
Nylon (DuPont)	.....	Natural cream and seven colors	10,500	13,000	3.00	250 to 400	1.14	0.012	Toughness and stability, for gears, nonlubricated bearings, valve seats, seals, packings. For gears and like parts nylon against nylon gives lowest wear, against steel next best. For corrosion applications stainless should be used. Brass or bronze affects nylon adversely.
Uscolite (U.S. Rubber)	.....	.....	5,500	.....	0.3	170	1.07	....	Toughness, high impact strength, water resistance, and resistance to many chemicals. For wire winding spools, ratchets, yarn spools, chemical handling equipment, etc.

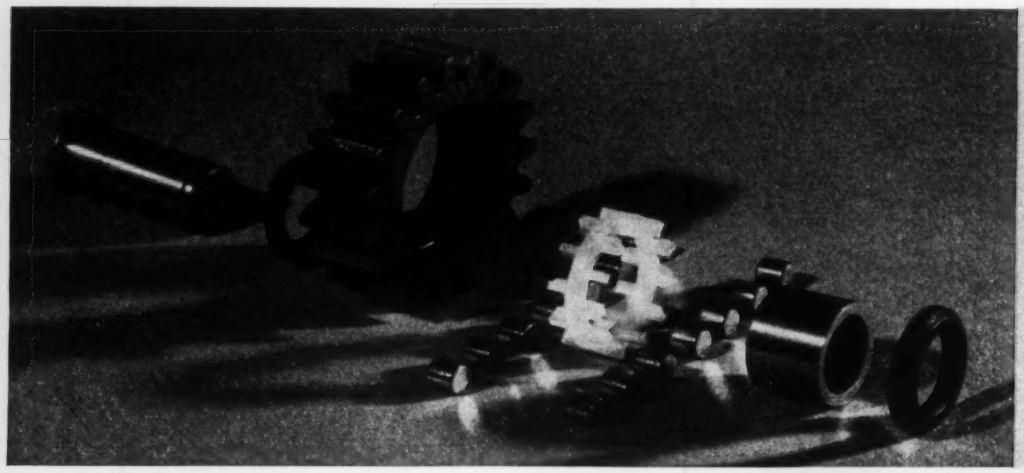


Fig. 36—Left—Pinion assembly for Bell helicopter transmission showing molded nylon bearing cage

Fig. 37 — Below — Magneto produced by J. I. Case Co. showing rotor disk molded by Barber-Colman Co. of Plaskon Alkyd 420 compound

threads 0.001 to 0.002-inch deep, and 0.003 to 0.004-inch pitch. Machining parts from nylon rods and tubes on automatic screw machines has proved economically sound in numerous instances in place of injection molding where quantities are moderate or where special design considerations make molding difficult.

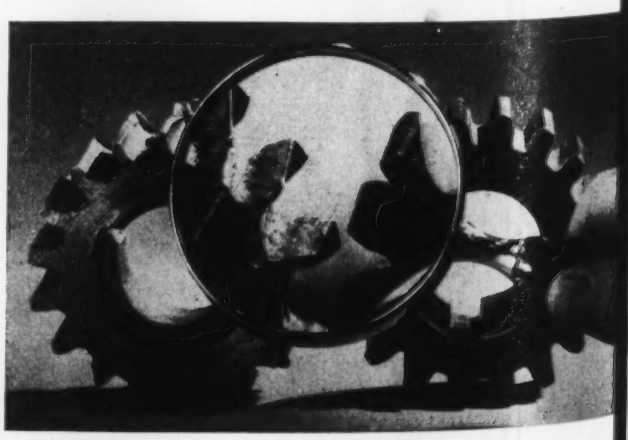
Nylon rod can also be centerless ground. Nylon balls are being manufactured in this way for valve seats, light load antifriction bearings, mechanical checks, etc. For close-tolerance work, the nylon is lapped similar to metal and the nylon balls can be held to a tolerance of $\pm$0.001-inch.

PLASKON ALKYDS: A third type of alkyd molding compound has been announced by the Plaskon Div., Libbey-Owens-Ford Glass Co., sole producer of this group of themosetting plastics which were first introduced in late 1948. The new material, designated Plaskon Alkyd 422, will be sold in granular form and is a flame-resistant compound with improved electrical properties. Comparable in most other respects to the present compounds of this type (Plaskon Alkyds 411 and 420), the new material is self-extinguishing under ASTM and Underwriters Laboratories flame-resistance tests.

The new alkyd compound retains its electrical properties on exposure to high humidities and temperatures and quickly regains its electrical properties after periods of immersion. Although water absorption in itself may not be deleterious to molded plastic parts, the electrical properties of such parts can be unfavorably affected by the presence of excessive moisture for prolonged periods of time. Since many electrical systems, particularly those used in military equipment, may be required to operate under damp or humid conditions, the practical importance of this improved moisture resistance is readily evident.

The new compound possesses the same fast rates of cure (molds about four times as fast as standard thermosetting plastics), the same high arc resistance, insulation and low loss properties, high heat resistance, and dimensional stability as the other mem-

Fig. 38—Comparison of metal gear, left, after 3 months' service in grinding wheel finishing lathe and Enrup gear, right, after 9 months' use



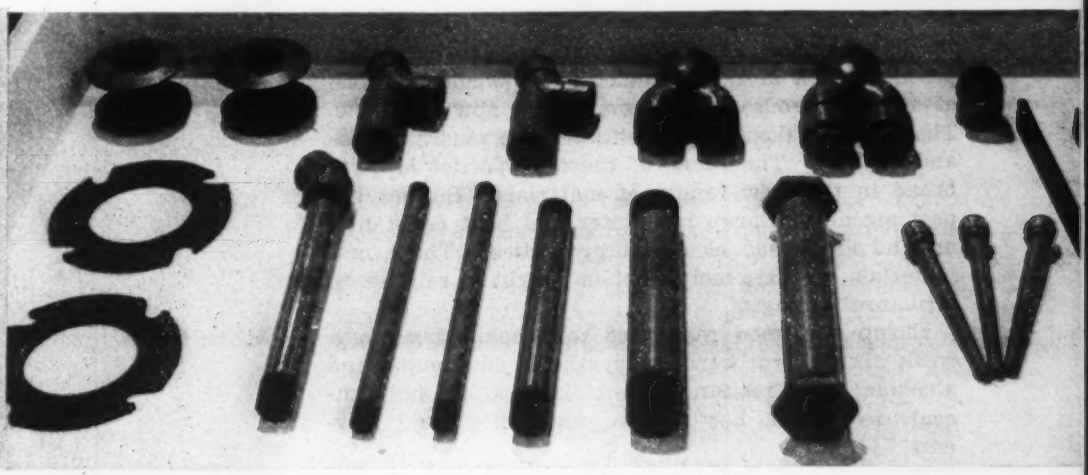
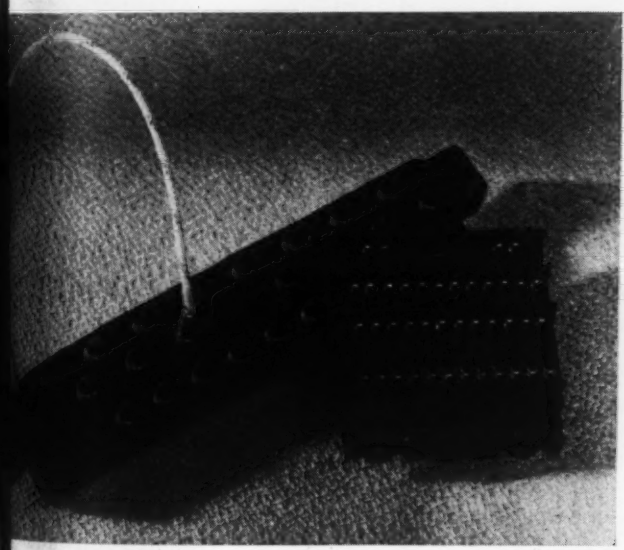


Fig. 39—Right—Group of Uscolite parts including chemically resistant pipe and fittings, cams for air-hose reels, wire spools, textile bobbins, and cathode strips used in electroplating

Fig. 40—Below—Terminal blocks for IBM equipment molded of woodflour-filled rubber phenolic. Cracking during assembly and use of the block were eliminated



bers of the alkyd family of molding materials. Comparison of alkyd properties with those of other plastics is given in TABLE 26.

Alkyd compounds lend themselves to high rates of production on self-contained, completely automatic molding machines that generally incur lower operating and tooling costs than conventional compression molding equipment and processes.

The alkyd compounds are finding wide use in civilian and military applications including television, radio and radar electronic components, automotive ignition system parts (*Fig.* 37), electrical switches and instruments, magnetic motor starters and other parts.

Silicone Alkyd Coatings: Three silicone alkyd coating resins have also been announced by the Plaskon Div. These are the first chemically combined silicone alkyd resins commercially available. The resins, designated Plaskon ST-856, ST-873, and ST-881 silicone alkyd resins, are expected to find wide use in military applications because of the following properties: resistance to heat, weathering, humidity, chemicals, and salt spray, and satisfactory performance under widely varying climates. Expected uses for silicone-alkyd resins are coatings for space heaters, transformers, motors, chemical and refinery equipment, etc.

The heat resistance of silicone-alkyd films is considerably higher than most purely organic films. High gloss and stable color in the range of 400 to 500 F are maintained by ST-856 and ST-873. The ST-881 resin for aluminum finishes shows no failure of film properties at temperatures as high as 1500 F. Hardness and abrasion resistance are reported equal to or better than the best melamine-alkyd combinations now in use. Resistance of a silicone-alkyd film to organic solvents and strong acids is reported to be particularly high and its alkali resistance is equivalent to the best baking enamels.

The ST-856 resin is a baking enamel for general industrial use where heat is deleterious to usual coating films and where durability in exterior or interior exposure is necessary. Its counterpart as an air-drying resin is ST-873 which can consequently be used for larger finishing areas than could be baked. ST-881 is a vehicle for aluminum or similar-pigment paints and has the advantages of durability, flexibility and adhesion plus ability to maintain its film properties at extremely high temperatures. Low temperatures have little or no effect on the silicone-alkyd films. All are intended to be used as one coat applications.

High Impact Strength Moldings: Shock-resistant properties of plastic moldings have been improved by several recent developments. In some compounds, plastics have been combined with rubber to give inherent shock resistance. Another method is the addition of fillers to certain compounds., These two techniques have been combined in some materials—their composition includes plastic, rubber and a filler. Such combination plastic materials offer very high impact resistance.

ENRUP: Produced by the United States Rubber Co., Enrup compounds are a new related group of thermosetting materials with properties combining

the desirable qualities of soft rubber and those of hard rubber and the brittle plastics. They are composed of high styrene-butadiene compounds plus one of the numerous rubber compounds now available. They possess flexibility and toughness, plus hardness and rigidity. The range of these properties is quite broad in this new family of materials. Besides impact strength, Enrup has water and heat resistance, and advantageous electrical properties. These new materials are extremely light in weight in relation to structural strength.

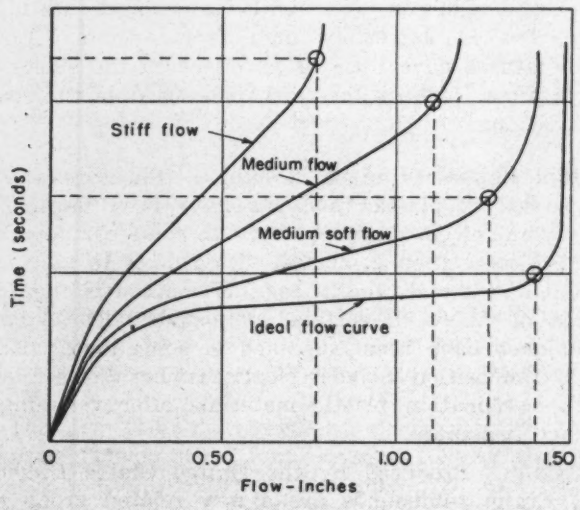
Enrup has good resistance to nonoxidizing acids, weak alkali, hydrocarbons, synthetic detergents, and alcohols; poor resisance to oxidizing acids, hot concentrated alkali, hot ketones, and chlorinated solvents.

For years, designers of plastics and rubber compounds have found themselves handicapped by the lack of a high-strength material, harder than about 80 Shore Durometer A and softer than about 60 Shore Durometer D. Nor was any thermosetting plastic available. Thermoplastics exhibited extremely poor srength and stability; rubber, to be acceptable in this range, required cloth or metal reinforcement. Enrup was the result of a U. S. Rubber research program directed toward filling this gap.

Best results in design are obtained when full advantage is taken of the new properties Enrup supplies. These properties may be adapted to specific applications, since compounding variations permit a wide range from a hardness of 85 Shore Durometer A with a modulus of 5000 up to Shore Durometer D with a modulus of 250,000.

Applications already found for Enrup include buttons or snubbers for automobile brakes to eliminate squeak, pipe for handling certain corrosive solutions, parts for electrical equipment, snubbers for automatic washing machines to eliminate lateral movement of the tub, gears for use in abrasive environment, etc. *Fig.* 38 compares metal and Enrup gears after service under abusive abrasive conditions.

Fig. 41—Comparative flow characteristics of general-purpose phenolic materials. Chart courtesy Plastics Div., Monsanto Chemical Co.



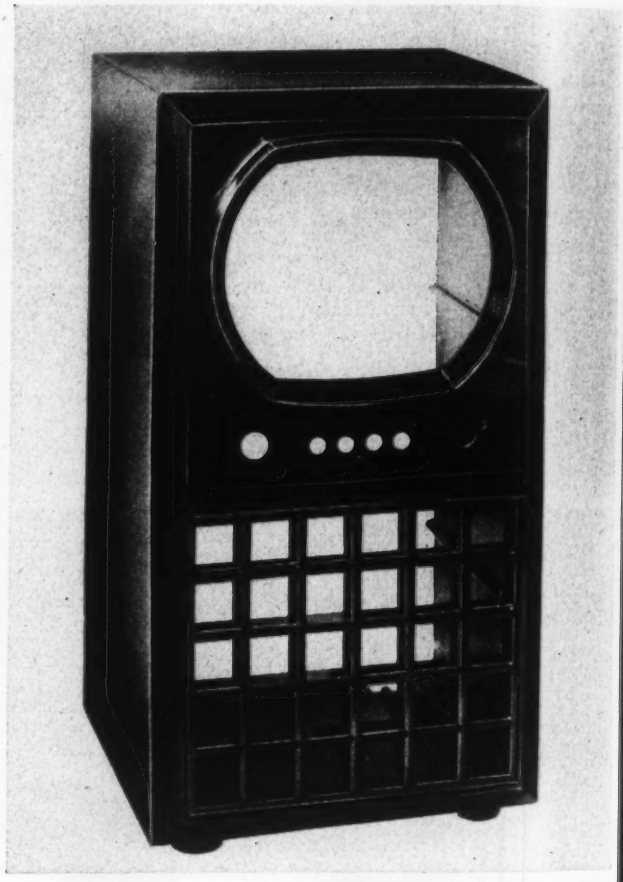


Fig. 42—Large molded Admiral television cabinet, weighing 42 pounds, which utilizes one of the new fast-flow phenolics recently developed

USCOLITE: A new thermoplastic material, Uscolite is produced in a variety of forms by the U. S. Rubber Co. and is not offered for molding by others. A blend of high styrene resin and acrylonitrile rubber, it is characterized by a unique combination of toughness with superior chemical resistance and low moisture absorption. Toughness and high impact strength are achieved without sacrifice of stiffness and other properties. Formulation and processing can be varied to produce different properties within a considerable range. Uscolite is especially suited for molded parts whose service conditions require that they possess, in combination, the properties of toughness, water resistance and chemical resistance.

Uscolite has been successfully applied for such parts as spools, flow regulating devices, nozzles, floats, threaded nuts and connectors, tool and machine parts, etc. A variety of parts for such applications are shown in *Fig.* 39. Chemical-resisting properties of Uscolite also recommend it as a material for the fabrication of various types of equipment

Fig. 43—Washing machine agitator molded of Durez 14899 Black phenolic

for storing, processing and handling corrosive solutions, fumes or vapors.

LUSTREX LT: Produced by Monsanto Chemical Co., Lustrex LT is a modified styrene plastic molding compound providing a good combination of moldability and physical properties. This thermoplastic material combines the thermal stability during molding and the dimensional stability of styrene with the high impact properties of the cellulosics. The shorter molding cycles associated with the production of styrene plastics can be further reduced through the use of Lustrex LT. This material can be readily fabricated on standard injection, compression, and extrusion machines employing essentially the same techniques used with general-purpose styrene.

The impact properties of Lustrex LT are three to five times that of general purpose styrene (0.8 to 1.2 versus 0.25 to 0.35 ft-lb per inch of notch) and the ultimate elongation is approximately ten times that of general-purpose styrene (10 to 15 per cent versus 1 to 1.5 per cent). Combined with these two properties are heat resistance, which is approximately 15 F higher than that of general-purpose styrene, good dimensional stability, low water absorption, excellent electrical properties, wide chemical resistance, and reasonable cost.

Lustrex LT is suitable for a wide variety of military and civilian applications. For military items, it is currently being used and is being considered for use in such applications as battery cases, housings, pipes, containers, and many classified items. For civilian applications, Lustrex LT is finding use in refrigeration, radio and television, and miscellaneous industrial fields.

RUBBER-PHENOLIC COMPOUNDS: Fillers of various types have been used for some time to increase impact strength of molded phenolics. The most recent further improvement is the additional blending of rubber with filled phenolics. General Electric Co. is marketing phenolics that utilize Hycar, a nitrile rubber trademarked by Goodrich. These compounds are made with woodflour, asbestos, flock, and fabric fillers.

General Electric devised a special "drop ball" test for the measurement of resilience in this type of material. Comparative results with regular filled phenolics and Hycar filled phenolics obtained by this test are given in TABLE 27. Great gain in impact resistance afforded by the added rubber is evident for all types of filled phenolic tested.

Durez Plastics & Chemicals Inc. is also making a special nitrile rubber and flock filled phenolic (Durez 13348) having high toughness and shock resistance. This material is very flexible and can be used in thin sections around large or odd-shape inserts. The material can be either compression or plunger molded, but is particularly suited for plunger molding.

In *Fig.* 40 is shown an application where benefits were gained by a change from conventional flock-

TABLE 27—DROP BALL TEST RESULTS WITH HYCAR PHENOLICS*

Type Material	Weight of Ball (grams)	Increasing Height Test (ft-lb) To Crack	Increasing Height Test (ft-lb) To Break	Fatigue Test (ft-lb) To Crack	Fatigue Test (ft-lb) To Break
Regular phenolic (woodflour) ...	95	0.924	1.508	0.714	3.34
Hycar-phenolic (woodflour) ...	173	3.33	9.48	4.80	37.935
Regular phenolic (asbestos)	95	0.421	0.421	0.48	0.48
Hycar-phenolic (asbestos)	131	3.14	6.50	0.997	7.90
Regular phenolic (cotton flock) .	131	1.621	5.54	0.521	7.65
Hycar-phenolic (cotton flock) .	173	4.12	14.34	13.05	51.61
Regular phenolic (rag)	173	3.155	10.03	1.76	15.546
Hycar-phenolic (fabric)	225	10.29	33.93	13.856	84.21**

* Description of test:

Specimen: A box 8 x 1¾ x 1¼ inch with $\frac{1}{16}$ inch wall thickness; blow is delivered to the center of the side of the box.

Selection of weight of ball: That weight which will crack the test specimen when dropped from not less than 13 inches nor more than 19 inches.

Increasing height test: The test is started at a height of 9 inches; height of drop is increased 1 inch after each blow; that height at which cracking and breaking occurs is noted.

Fatigue test: 75 per cent of the cracking height is used as a base; ball is dropped repeatedly from this height; number of blows to crack and break are noted.

Calculations: Total ft-lb of energy to crack and break are calculated for each specimen; these values are averaged and reported as an energy value for each type of compound.

** Not completely broken.

filled phenolic to GE's woodflour-filled rubber phenolic. Cracking of the terminal block was eliminated both when the metal contacts were press-fitted and crimped into position and when, in use, tapered plugs on the connector wires were inserted in the contacts.

LARGE MOLDINGS: Use of phenolics on large moldings such as television cabinets has accelerated research on improved molding properties. When the present international emergency arose, other large housings such as air conditioner housings were approaching production. These applications prompted the development of materials that flow more freely at lower molding pressures than those used heretofore, but that also polymerized or cured at least as rapidly as the phenolics previously used in molding smaller parts.

Flow characteristics of such materals are graphically illustrated in *Fig.* 41. The medium-soft-flow curve illustrates the flow properties required for TV cabinets weighing 35 to 40 pounds, compared to the usual stiff and medium-flow materials used on smaller parts, and to the ideal flow curve of the truly general-purpose materials.

In *Fig.* 42 is shown the latest of the molded phenolic TV cabinets, the 42-pound Admiral console. This is molded at a pressure of approximately 1000 tons and is cured in approximately 6 minutes.

Another large molding is shown in *Fig.* 43, a washing machine agitator. Durez 14900 Black, a phenolic compound having resistance to water and detergents, is employed for this part. In such applications, Durez 14899 Black is also being used. This material is a flock-filled phenolic with higher impact strength and can be either plunger or compression molded.

Laminated Plastics: Industrial grade laminates are finding many uses in both mechanical and electrical components: sleeve bearings, ball bearing cages, gear stock for silent operating or corrosion-resistant gears, pulleys, bobbins, panels, terminal strips, spacers in electrical equipment, etc.

Properties and applications of some relatively new laminated sheet materials are given briefly in TABLE 28. These specific types are those produced by the Continental Diamond Fibre Co. An exceptional range of properties is available by virtue of the use of widely differing laminate materials: paper-base phenolics, cotton mat filled phenolic, glass fiber filled silicone resin, and Teflon impregnated glass fabric. Most of these materials are also available in other forms, such as rod and tubing. A unique variation of the Teflon and glass fabric combination is available as a copper-clad sheet for special applications.

These laminates can be readily sawed, turned, drilled, milled or tapped, although extra care must be exercised with some grades when drilling or tapping parallel to laminations. Punching and shearing can be performed cold with some grades and thick-

TABLE 28—PROPERTIES OF NEW LAMINATED PLASTIC SHEET MATERIALS*

Type	Maximum Sheet Size (inches)	Thickness Range (inches)	Color	Tensile Strength (psi)	Flexural Strength (psi)	Water Absorption (% 24 hr)	Specific Gravity	Outstanding Properties	Applications
Paper-base phenolic (Dilecto XXHV-2).	46 x 70	$\frac{1}{64}$ to 2	Natural	9,500	15,000	0.4 to 1.0	1.27	High dielectric strength parallel to laminations	Spacers and insulation for high-voltage equipment
Paper-base phenolic (Dilecto XXXP-26)	38 x 42	$\frac{1}{64}$ to ¼	Natural	12,500 to 17,000	18,000 to 21,000	0.2 to 0.4	1.27	High resistance, low dielectric loss, dimensionally stable, no blistering up to 300 F.	Switch stators and rotors, transformer terminal plates, etc., for electronic equipment
Nonwoven cotton mat filler with phenolic varnish (CRD) ...	38 x 48	0.015 to 2	Natural	14,500	21,000	0.9 to 1.6	1.34	Excellent machinability, mechanical strength, impact-fatigue resistance, and wear resistance	Textile bobbin heads, fine-pitch gears
Glass-fabric base with silicone resin bond (GB-112S)	37 x 42 13 x 36	0.010 to 1 1 to 2	.....	27,000	30,000	0.13 to 0.35	1.68	High heat resistance (to 400 F cont.), excellent electrical properties, high mechanical strength, chemical resistance	Wedges and liners for high-temperature motors, high-frequency and arc-resistance applications
Teflon and glass fabric combination	16 x 37	0.008 to ½	.....	17,500	22,000	0.02 to 0.30	2.2	High heat resistance (to 570 F int.), excellent electrical properties, resistant to practically all chemicals	Motor slot liners and wedges, coil separators, insulation

* Courtesy Continental Diamond Fibre Co.

nesses. In other cases, heating the material permits such operations to be performed without any great difficulty.

Molded Laminates: High mechanical strength and impact resistance of molded laminates, combined with light weight, give an ideal structural material for many applications. Techniques for the production of molded laminates take a variety of forms, such as high-pressure compression molding, low-pressure molding, and low-pressure "air-vacuum" injection molding. One of the design advantages afforded by this variety of methods is the almost unrestricted size range possible in molded parts.

HIGH-PRESSURE MOLDING MATERIALS: Several new high-compression molded laminate materials have been introduced by the Formica Co. Known as Formica grades Z-80 and Z-65, these materials have been developed primarily for use in 60-cycle applications as specialized electrical insulation. Grade Z-80 is a coarse-weave fabric-base laminate, whereas Z-65 is a paper-base laminate. Both grades are impregnated with a special resin that provides high arc resistance, low loss properties and good dimensional stability.

These new grades have good punching and excellent machining qualities. They are available in sheet form from 1/32 to 1 inch thick, natural color, semi-gloss finish. Where desirable for parts too complicated for straight laminated molding, macerated molding can be employed. An application of macerated-molded Formica Z-80 is shown in *Fig.* 44.

A new adaptation of an established Formica material is being made by machine tool builders and others for use in bearing surface applications. Developed at the request of the G. A. Gray Co., sheets of Formica grade C are being molded with laminations perpendicular to the load. This molded-lamination construction is successfully carrying loads up to 180,000 pounds. Scoring and cutting common to cast-iron surfaces are eliminated with this material. Properly lubricated, it reduces friction to a negligible factor. Another important characteristic for high-speed operation under heavy weight is the heat-insulating quality of the surfaces. This means that heat cannot easily penetrate to the metal structure supporting the laminate to cause distortions.

Monsanto Chemical Co. has developed a new thermoplastic structural material called Lustrex Loaded Glass Mat. It is produced by impregnating a mat structure of glass textile fibers with a high concentration of styrene applied from an aqueous dispersion of the resin. Being thermoplastic, the resulting sheet material may be readily formed by molding to shape between heated steel dies in conventional compression molding equipment.

Products made from Lustrex Loaded Glass Mat combine the attractive appearance, dimensional stability and excellent electrical properties of styrene with the high mechanical strength of fibrous glass. A wide range of decorative effects is possible either by pigmenting the resin prior to impregnation, which provides "molded-in" coloration, or by surface coating with special lacquers developed for use on styrene.

Lustrex Loaded Glass Mat is recommended for the manufacture of panels, housings, containers, structural laminates, electrical devices and for general industrial use requiring a material with high impact strength and resistance to chemical attack.

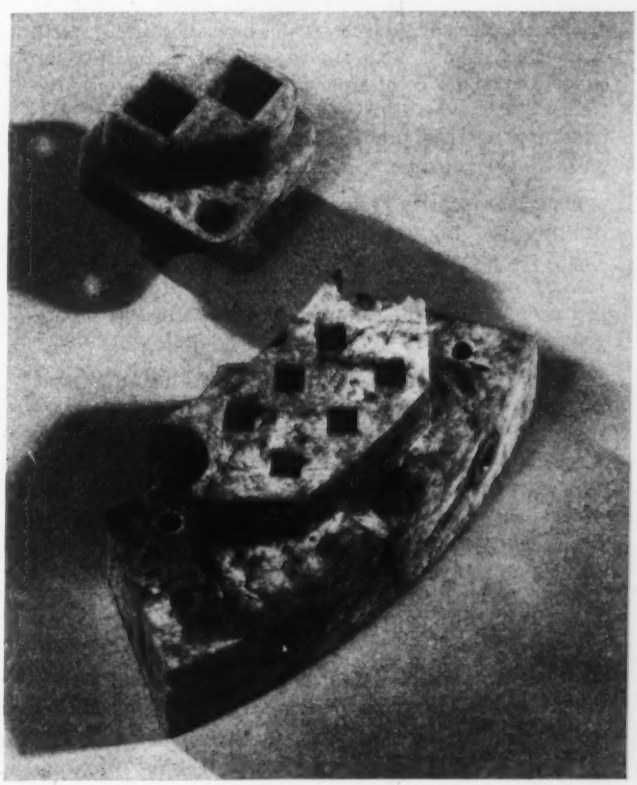
LOW-PRESSURE MOLDING: This field of reinforced plastics gained first prominence in World War II. Then, glass reinforced polyester plastics were used in aircraft fuel tanks, wing parts, radar domes, housings, etc. These applications drew upon several outstanding properties of the material: high strength-weight ratio, dimensional stability, and resistance to attack from moisture, chemicals, and rot. Increasing interest in low-pressure and contact-pressure laminating and molding has led to the development of a variety of new polyester resins, special types of phenolic resins, and reinforcing fillers.

Of equal interest to the designer are the materials and the methods for low-pressure molded constructions. Discussion of the several molding methods and their potential advantages for different types of design are covered in other sources.* One technique is outlined in the following section because it represents a new approach to molded laminates.

With respect to materials, the fillers chiefly used are glass fibers and fabrics although cotton, rayon, nylon, etc., are also employed. The plastic resins are diverse in number and properties. Many are custom

* See *Production Processes—Their Influence on Design, Vol. II,* by R. W. Bolz, Penton Publishing Co., Cleveland, 1951.

Fig. 44—Macerated-molded Formica Z-80 brush pads used in electric deicing assemblies by Hamilton Standard Div. of United Aircraft Corp.



compounded for specific applications. Some idea of the range of basic plastics for low-pressure molding is given by a brief description of Bakelite Co.'s line of polyester and phenolic resins.

Bakelite Polyester Resins are combinations of styrene monomer and complex polyesters. The resins are thermosetting in nature. Polymerization is effected by use of catalyst, application of heat, or both. The resins are supplied as pale liquids in varying viscosities. They are produced, at present, in several grades, each best suited to certain end uses, as follows:

General-purpose liquid resin developed for structural applications. It is particularly serviceable for matched die molding because of its excellent moldability and easy flowing characteristics. However, it can be employed in all the common types of molds in current use today, including plaster, wood, and sheet metal, and is applicable to rubber-bag molding. It is adaptable to molding at both room and elevated temperature and requires only standard catalysts. It does not precure. It retains its excellent mechanical strengths and electrical values at operating temperatures under 150 F.

Flexible resin supplied as a nonplasticized liquid. It can be used alone for certain applications requiring a high order of toughness and flexibility, as in the production of tubing. However, it has found greatest service to date as a modifier for use with other polyester resins to impart toughness and resistance to impact in structural laminates and moldings. It is recommended chiefly for mechanical applications, and is not intended for use where the electrical insulating requirements are critical.

High-viscosity resin (4000-6000 cst.) for casting or molding. Such castings or moldings are produced with less inherent stresses and strains than with other grades of polyesters. This makes it possible to produce noncrazing pieces of high-resin content, with or without filler. With fillers, smaller quantities can be employed as compared with other polyesters. Because of the versatility of this resin, it is very satisfactory for the production of castings made from glass-fiber preforms.

Medium-viscosity resin (300-600 cst.) developed especially for high-frequency insulation requirements (9375 megacycles per second). It approaches the following low-viscosity resin in electrical properties, but is handled somewhat more readily because of its improved moldability.

Low-viscosity resin (150-400 cst.) first developed for glass-fiber radar housings and electrical equipment in World War II. When cured, it has superior low-loss properties that make it particularly useful for high-frequency insulation. Its low viscosity provides ease of impregnation or wetting of the fibers. It is somewhat more difficult to mold than other grades of polyesters, in that it must be held at a low temperature for a period of time in order to insure relatively void-free structures.

A similar family of polyester resins has been developed by Naugatuck Chemical, a division of U. S. Rubber Co. Known as Vibrin, these resins are compositions of polyesters and cross-linking monomers. Possessing excellent resistance to aging and to chemical reagents, the cured resins range from soft, flexible types to very hard and rigid. Self-extinguishing types are available. The Vibrin resins are offered in consistencies ranging from low-viscosity liquids to wax-like solids.

Bakelite has also developed a phenolic resin particularly for application on glass-fiber textiles, both mat and woven, to produce high strength laminated structures at low and contact pressures. This resin has remarkable affinity for glass fibers. The exceptional wetting properties of the resin make possible laminated structures that take fullest advantage of the mechanical strengths inherent in the glass fibers. Material treated with this resin can be handled in dry form for low and contact-pressure molding. Another advantage is derived from the range of pressures that can be employed with this resin, from 10 psi to 500 psi without injury to the glass filaments. Usually, it is necessary to mold glass cloth at less than 25 psi.

Experimental panels made with one-way glass warp fibers have yielded such test values as 190,000 psi flexural strengths, flexural modulus of 7,000,000 psi, tensile strengths of 140,000 psi, impact strength of 72 foot-pounds. These are maximum figures, but they represent a goal that can be achieved through proper handling and technique.

This material can be fabricated with glass-fiber textiles in matched metal molds. It has also been used successfully in the production of glass cloth rolled tubes at contact pressure.

New C-8 resins developed by Bakelite are based on phenols and resemble polyester resins in method of use. They set in a few hours, self heating from room temperature or can be cured rapidly by application of heat. When the C-8 resins are held in thin films at temperatures below 100 F, only partial cures are obtained. Thus, they should be allowed to self heat

Fig. 45—Laminated housing for a radar antenna approximately 5 feet in diameter

to 200 F or higher to attain greatest strength values. Contact pressure alone is sufficient. Shrinkage of C-8 resins on curing is lower than the conventional phenolic resins, and considerably lower than the polyester resins (½ per cent in length and less than 2 per cent in volume).

The C-8 resins have excellent adhesion to glass cloth, yielding laminates with high bond strength. An outstanding application at present is their use in orthopedic braces and prosthetic appliances which are laminated-molded from woven glass cloth.

These resins have unusual electrical properties for dc and ac service. They demonstrate excellent chemical stability (nondeterioration) at high temperatures in the order of 390 F. They also have excellent chemical resistance, particularly to alkalies.

Only a suggestion of the potentials of low-pressure laminates in design, *Fig.* 45 shows a 5-foot diameter laminated housing for a radar antenna. Perhaps the most dramatic application of polyester resins to date is their use for the hulls of 36-foot Navy LCVP's.

AIR-VACUUM INJECTION MOLDING: This new technique for molding laminate structures is aptly described in terms of the production of a representative design—a housing for a photoelectric engraving machine manufactured by the Fairchild Camera and Instrument Corp. Le Conte Plastics Co. is making the housing of American Cyanamid Co.'s Laminac polyester resin, reinforced with two layers of Fiberglas. A copper screen also incorporated in the "lay-up" serves to ground stray electrical currents.

To produce this housing, Le Conte began by making a plaster model of the housing, applying a parting agent to it, then casting a female form in plaster from the model. The model was removed and replaced by pattern-makers' wax. Against this wax, a plaster male form was molded. Then aluminum molds from these two plaster ones were made by a foundry.

Production of the housing itself begins by cutting to pattern the two layers of Fiberglas and the copper screen. For preliminary shaping, these sheets are stapled to a wooden male form that corresponds to the male part of the mold. The sheets are put in the aluminum female mold and the mold is closed with the male one. Because a smooth surface is needed on both sides of the housing, and because hardly any pressure is used during the molding, the resin must be applied after the mold is closed, which presents an interesting production problem.

Le Conte developed a process of injecting the resin into the mold from a specially designed resin pot. The pot is connected to a small opening in the mold by a hose. To make the resin flow through the hose, two other connections were made, one for exerting air pressure in the pot, another for creating a light vacuum in the mold. The latter connection, in addition to aiding in the resin flow, eliminates "starved spots" caused by trapped air.

When the mold is filled, it is cured in an air circulating oven. Then the housing is removed from the mold and placed on a jig to insure uniform trim. The parting line is finished by a sawing operation.

This new reinforced-plastic housing replaced a metal housing welded of five different stamped parts. Tolerances with the plastic housing were more easily maintained. Substantial savings were realized in both production of the housing and in its assembly with other components.

Fig. 46—Large propeller blades manufactured by Hamilton Standard Div. of United Aircraft Corp. are filled with a special Hycar-base expanded plastic. Material keeps blade shell from vibrating and resists impact

Cellular Plastics: Several new expanded plastics have recently been developed. They are available in a wide range of properties for some of the more-unique applications of plastics in design. For example, an airplane propeller filled with an expanded plastic is now in manufacture at the Hamilton Standard Div. of United Aircraft Corp., *Fig.* 46. Light and hard, the material is used to fill the void between propeller blade core and shell. The hard sponge keeps the core from vibrating in and out under extreme pressures, and supports it against the impact of rocks, ice, and other material thrown up by the plane's undercarriage.

This new filling compound developed by Hamilton Standard, called HS 160, has three principal components: Hycar OR-15, an oil-resistant rubber manufactured by B. F. Goodrich Chemical Co.; phenolic resin and nylon. The blowing agent used to foam this rubber-resin blend up to eight times its former

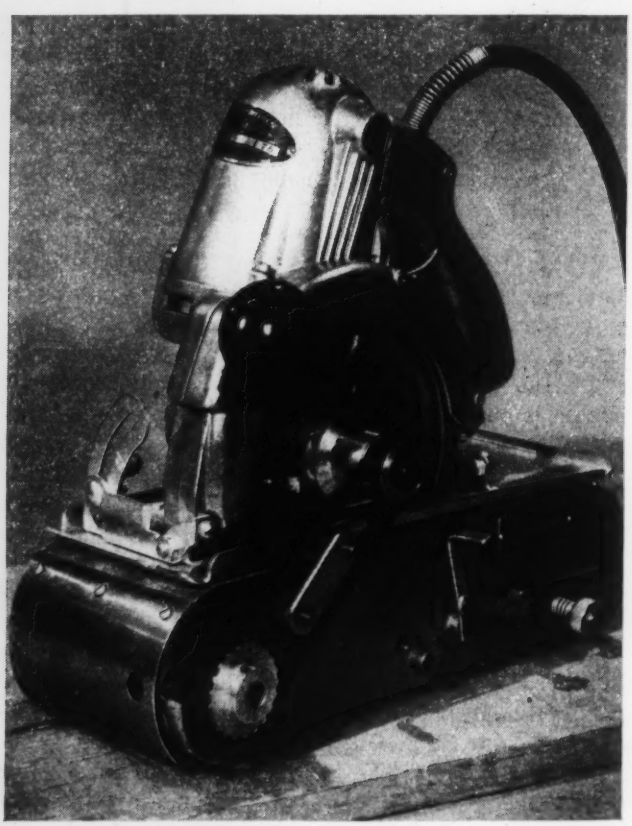
mass is the highly reactive chemical, azodiisobutyronitrile. After foaming under 300 F temperatures, the compound cools into a light, rigid structure which fills the aperture between propeller core and blade edges, and the hollow core itself. HS 160 is so compounded that high centrifugal loads will not cause it to shift after its installation.

Another adaptation of Hycar in expanded materials is known as Hycar PA-21. This compound, developed by the Sponge Rubber Products Co., is substantially lower in price than cellular silicone rubber but with much of the same high-temperature resistance. Its use is desirable in commercial and defense applications such as grommets, pads, gaskets, and shock mounts requiring resistance to ozone, oil, and gasoline, and excellent compression set properties. In performing at intermittent temperatures of 400 F and for a week continuously at 300-350 F, the new stock contrasts with standard crude stocks which melt after a few hours at 300 F.

Open or closed-cell structure is available, the open-cell material having poor resistance to water in that it swells. The closed-cell material is practically impervious to water. Developed to function at high temperatures, the new cellular rubber stock is not efficient at temperatures below freezing. Other stocks of crude which perform at −94 F are available for such temperatures.

Called Spongex Plastic No. 1, another new expanded plastic, unicellular polyvinyl chloride, is being successfully compounded by the Sponge Rubber Products Co. This new material is especially suited for flotation devices because of its light weight, low moisture absorption, and unicellular composition. Various densities can be formulated ranging from 2 to 12 pounds per cubic foot. Its compression range can be varied from 1½ to 150 pounds per square inch. Its use in structural sandwich construction is recommended by an application which uses only the rigidity of the company's hardest version (25 per cent compression-deflection at 50 psi) of its 2.5 pound per cubic foot density as a structural member. Other properties of this application include excellent resistance to ozone and weathering. Spongex is available in sheets, slabs, and molded shapes.

Fig. 47—Portable sander and saw employing Gilmer neoprene timing belt. Photo, courtesy U. S. Rubber Co.



Engineering Fabrics: A whole new family of industrial fabrics has recently been developed by the Connecticut Hard Rubber Co. These fabrics, known as "Cohrlastic," offer a wide range of properties by virtue of their utilization, in combination, of materials such as Fiberglas and the newer heavy-duty synthetic rubbers and plastics.

The first of the Cohrlastic series, silicone rubber coated Fiberglas, has been on the market for about five years and has already found many industrial applications. The outstanding property of these fabrics is their resilience and pliability over a temperature range of −75 F to 500 F. One of their principal uses is in temperature-resistant seals and gaskets. They may also be formed into conveyor belts for light service, into flexible ducting, into heat sealing jaws for plastic sealing equipment and into seals for the Dietrich wall and expansion joints for large boiler installations. The fabrics have excellent dielectric strength and can be used in many electrical applications. They are resistant to most chemicals, except the aromatic and chlorinated solvents, and they do not affect most other materials in which they come in contact. In fact, very few materials will even adhere to the silicone rubber surface, which makes them ideal for handling many adhesive substances.

A newer member of the family is a silicone rubber coated Orlon fabric which has proved particularly desirable for use in heat-resistant diaphragms. The use of Orlon instead of Fiberglas as the reinforcing material gives a fabric that is softer, much more flexible and flex resistant but with the sacrifice of some heat resistance. The material may be used down to −100 F but not much over 300 to 325 F.

Silicone rubber on nylon also has interesting diaphragm uses. The use of nylon with its greater strength, in place of Orlon, permits deeper convolutions in the diaphragm but with somewhat less heat resistance.

Two new Cohrlastic fabrics now in the laboratory of the Connecticut Hard Rubber Co. will be available soon and should widen the use of materials of this type. They are Fiberglas-Teflon and Fiberglas-Kel-F combinations.

Teflon on Fiberglas gives a fabric that is resistant to practically all substances, with a service temperature range of −100 F to 500 F. It is ideal as a gasketing against chemicals or rocket fuels; as a diaphragm in contact with aromatic or corrosive substances; as protective clothing, or in any other use where high chemical resistance is desired. An interesting feature of this fabric is the greatly improved cold-flow characteristics due to the reinforcement.

Kel-F on Fiberglas has many of the same properties. This fabric is slightly less chemical and heat resistant than Teflon on Fiberglas but has better flexibility and pliability making it more suitable for diaphragms or similar uses.

RUBBERS

Selection of Rubbers: Designers are often handicapped in selecting the proper resilient material for a given service because data on the properties of elastomers are either lacking in detail or confusingly complex. This situation stems directly from the method of manufacture. The characteristics of rubber products are controlled by the choice of compounding ingredients and variations in processing techniques, and it is possible to modify properties within rather wide limits without penalizing production efficiency. To add to the variety of obtainable properties, a number of chemical rubbers are now available, each having a different range of properties than that of natural rubber and the same or greater compounding latitude.

Properties of natural rubber and the various synthetics are compared with general terms in TABLE 29. This table appears in the published literature of the Acushnet Process Company, a large molder of industrial rubber parts and one with extensive experience in the manufacture of many kinds of rubber goods. Their ratings are the result of experience with a large variety of compounds made from all kinds of rubber and are practically a consensus of the rubber industry. Recent advances in some of these general types are covered in the following sections.

Neoprene: Most data on neoprene compositions deal with the retention of physical properties under adverse service conditions, since it is in this respect that neoprene products are outstanding. However, this kind of data underemphasizes the excellent basic properties of neoprene. TABLE 29 shows that in most physical properties neoprene is rated better than average, particularly in such characteristics as tensile strength, resilience (rebound), and in resistance to oil and gasoline. Two important properties of resil-

TABLE 29—GENERAL PROPERTIES OF VARIOUS RUBBER COMPOUNDS*

Chemical and Physical Properties	Natural Rubber	GR-S or Buna S	Nitrile Rubber or Buna N	Neoprene	Butyl
Composition	.....	Butadiene styrene	Butadiene acrylonitrile	Chloroprene	Isobutylene-isoprene
Tensile strength (psi)					
Pure gum	Over 3000	Below 1000	Below 1000	Over 3000	Over 1500
Black	Over 3000	Over 2000	Over 2000	Over 3000	Over 2000
Practical hardness range (Shore Duro A)	30-90	40-90	40-95	40-95	40-75
Rebound					
Cold	Excellent	Good	Good	Very good	Bad
Hot	Excellent	Good	Good	Very good	Very good
Tear resistance	Good	Fair	Fair	Fair to good	Good
Abrasion resistance	Excellent	Good to excellent	Good	Excellent	Good
Sunlight aging	Poor	Poor	Poor	Very good	Very good
Oxidation	Good	Good	Good	Excellent	Excellent
Heat aging	Good	Very good	Excellent	Excellent	Excellent
Solvent resistance					
Aliphatic hydrocarbons	Poor	Poor	Excellent	Good	Poor
Aromatic hydrocarbons	Poor	Poor	Good	Fair	Poor
Oxygenated solvents, alcohols (ketones, etc.)	Good	Good	Poor	Poor	Good
Oil and gasoline	Poor	Poor	Excellent	Good	Poor
Animal and vegetable oils	Poor to good	Poor to good	Excellent	Good	Excellent
Acid resistance					
Dilute	Fair to good	Fair to good	Good	Excellent	Excellent
Concentrated	Fair to good	Fair to good	Good	Good	Excellent
Flame resistance	Poor	Poor	Poor	Good	Poor
Permeability to gases	Fair	Fair	Fair	Low	Very low
Electrical insulation	Good	Good	Poor	Fair	Good
Water swell resistance	Fair	Excellent	Excellent	Fair	Excellent

* This table presents comparative properties that the industry has found through experience. There may be exceptions to these properties where special compounding techniques are used.

ient parts for machinery are not included in the table. With respect to low compression set and flex life, neoprene compounds are well rated—as good as those of any of the rubbers and better than most.

Neoprene in general is used in parts requiring several properties combined in one composition. For example, an all-rubber drive belt, *Fig.* 47, requires low permanent set, long flex life and a high degree of oil resistance. In any one of the three properties, there are elastomers which are as good or better than neoprene. But neoprene is the probable choice because it adequately meets all the requirements. Natural rubber is as good as neoprene in point of permanent set and flex life, but not in resistance to oil. On the other hand, compositions based on other chemical rubbers may show equal oil resistance, but might be deficient in either permanent set properties or flex life, or both. In short, neoprene is seldom chosen because of superiority in any single property, and it is rarely rejected because of any outstanding weakness.

The following discussion presents a brief summary of some recent trends and advances in the use of neoprene.

NEW LOW-SET NEOPRENE: To machine designers, the most important development of recent years was the introduction, late in 1949, of a new type of general-purpose neoprene having improved permanent set and cold flow characteristics. Previous neoprenes were satisfactory when used under normal temperature conditions, but they were inadequate at temperatures of 250 F and above. The new neoprene is of particular value in such products as seals and engine mounts. Since the introduction of the new polymer, neoprene has become almost standard for aircraft engine mountings which require a combination of good dynamic properties, resistance to oil and ozone, low permanent set and cold flow, and of more importance, the ability to retain these properties unimpaired at high operating temperatures.

FLOWED-IN SEALS: The can maker flows a thin ring of rubber, either latex or solvent solutions, around the outer edge of the can lid, dries and cures it. Sealing is effected by crimping the lid to the can body, usually after filling. Design engineers have recently adapted this technique to the design of seals for drawn metal products. One industrial use is a flowed-in neoprene seal for a hydraulic shock absorber. The sealing gasket is formed in place and requires no assembly operation. The process of making the seal is easily adapted to mass-production methods. Advantages of the flowed-in seal in production are the elimination of the seal ring as a separate component to be handled in assembly and the minimizing of rejected assemblies because of improperly positioned seals.

Thiokol Compounds: True elastomers that possess the best overall solvent resistance of the commercially available rubbers, Thiokol compounds are not seriously affected by petroleum hydrocarbons, esters, ethers, ketones, alcohols, water, and aromatic blended fuels. They should be considered for applications requiring resistance to solvents generally. They also have excellent aging properties, resistance to sunlight, and to ozone. They maintain their flexibility at low temperatures and plasticizers are not required to obtain flexibility at temperatures as low as −70 F. These are special-purpose polymers and should not be confused with general-purpose rubbers such as natural rubber or GR-S.

In order to illustrate where and how these products can best be used, a short review of the various products commercially available and their properties is presented. The crude rubbers are useful in the manufacture of oil-resistant mechanical rubber goods such as lacquer, solvent, and paint spray hose. Oil-resistant gaskets, washers, packings, and diaphragms are also fabricated from these rubbers. Permanent putties which are also oil-resistant can be made from them. They find their greatest use in applications requiring a minimum of swell and freedom from shrinkage when in contact with active solvents and reagents.

Water dispersions are used primarily in the formulation of caulking compounds for aircraft and for protective coatings. The caulking compounds are used both for sealing pressurized cabins and gasoline tanks. The properties that make them useful here can also be utilized for the sealing of any fabricated structure, whether metal, wood, glass, or plastic. In protective coatings they are used primarily to flexibilize such resins as the vinyls where a nonextractable plasticizer is required.

Perhaps the most interesting new development in the Thiokol synthetic rubber field is the bringing of a true liquid polymer into widespread commercial use. This polymer is 100 per cent polymerizable and can be converted in place to a tough resilient rubber. It converts without shrinkage and consequently has found many interesting applications. It is helpful in pattern shops in the rapid preparation of complicated molds. Flexible molds made from it have exceptionally good accuracy coupled with good dimensional stability. These molds can be stripped from complicated forms and undercuts without damage to either the mold or the master. It can also be used to reproduce complicated masters from rigid molds. Similarly such molds are of considerable interest in the ceramic and related industries. The liquid polymer can also be used for potting and filleting and because of its unusual rubbery characteristics, solvent resistance, resistance to thermal shock and good aging characteristics, is finding wide acceptance in the electrical fields, the marine fields, and the process industries.

Compounds prepared from Thiokol liquid polymer are usually supplied as two-part compositions. These are mixed together just prior to use and after mixing have a working life of from a few minutes to several hours depending on the requirements. They set up to a tough rubber in three to twenty-four hours under most operating conditions.

A more recent development in this field is the use of this liquid polymer for impregnating leather. Being a liquid, it fills the voids of the leather easily. When converted it is totally insoluble in practically all solvents. By special treatments the leather can be kept soft and pliable such as might be required for diaphragms, or stiffened up considerably such as would be required for high-pressure packings. Such leather gives the designer a new composition with which to work—one having the mechanical strength and wearing qualities of leather coupled with the impermeability of rubber.

Silicone Rubber: First produced in commercial quantities for military requirements about eight years ago, silicones were not generally available to industry's engineers until 1945. These new semi-inorganic engineering materials were a few fluids, varnishes, compounds and rubbers that to all appearances were the same as corresponding organic materials. Most of those early silicone products could be handled in the same manner as organic materials. But there the resemblance ended. For, unlike their organic counterparts, the silicones withstand abnormally high and low temperatures; they possess excellent dielectric properties; they are moisture resistant and water repellent; they have good oxidation resistance and are relatively chemically inert. These properties are the reason why the demand for silicone products has reached major proportions in the few years they have been available. The large demand for these unique materials is in turn responsible for increased production which has helped eliminate one of the major objections to silicone products—their cost.

There are today over 100 different silicone products or materials available to the industrial and consumer markets. Among these, silicone rubbers are one of the most important because they offer designers significantly improved high-temperature elastomeric properties.

Dow Corning's silicone rubber—Silastic—has been developed into a number of new stocks which greatly increase the usefulness of these semi-inorganic, rubberlike materials. Resistance to permanent compression set has been tripled in another group of Silastic stocks. The mechanical strength of some stocks has been improved considerably.

In general, silicone rubbers remain serviceable from temperatures below −100 F to above 500 F, 550 F being considered the top service temperature. All types of silicone rubber withstand continuous exposure to temperatures of at least 300 F for an indefinitely long period of time. That gives them a minimum advantage of about 100 F over organic rubbers. In most applications, these rubbers will withstand continuous long-term exposure to temperatures in the range of 300 to 500 F, *Fig.* 48. Other properties include excellent resistance to oxidation and to outdoor weathering; good resistance to many oils and to a variety of chemicals; and dielectric properties that remain relatively constant over a wide temperature span and over a broad frequency range.

Physical properties vary widely with different formulations. Ranges of some properties are as follows: Specific gravity, 1.1 to 2.5; hardness, Durometer A scale, 35 to 95; tensile strength, 300 to 800 psi; ultimate elongation, 40 to 400 per cent; brittle point, −90 F to less than −165 F; compression set, after 22 hours at 300 F, 10 to 90 per cent.

Fabrication methods for silicone rubbers are very similar to those used in forming conventional rubbers. The major difference lies in the oven curing at high temperatures required to develop optimum properties in the finished part; for instance, 24 hours cure at 480 F required for one stack. A variety of forms into which these rubbers can be fabricated is shown in *Fig.* 49. To offset the disadvantage of low tear resistance in production, General Electric has developed a new silicone rubber stock designated as compound 81223. This rubber stock is specifically formulated for those applications requiring a heat-resistant rubberlike material possessing greater elongation and

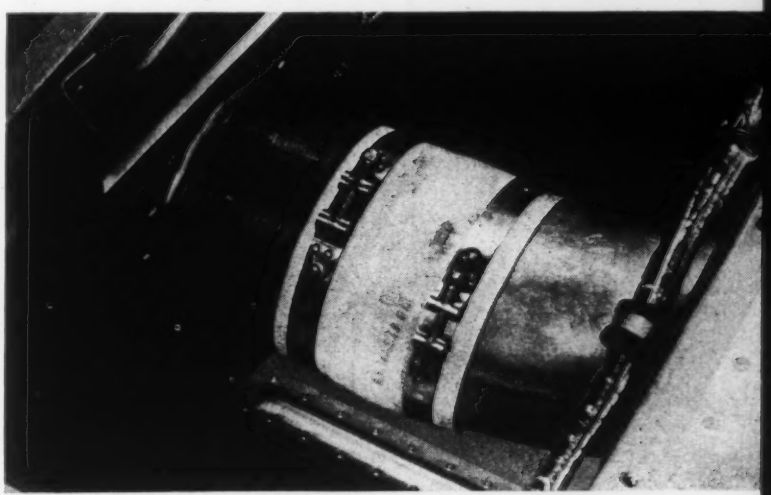


Fig. 48—Above—Silastic-coated glass cloth heating duct seal which withstands continuous operating temperatures between 350 and 450 F on Convair-Liners

Fig. 49—Below—A variety of Silastic (silicone rubber) molded parts showing range of design

hot tear strength than former silicone stocks. This added ease in fabricating parts with undercuts as well as low specific gravity (1.1 to 1.2) and neutral light tan color suitable for tinting make this new material of particular interest.

SILICONE RUBBER MECHANICAL PARTS: These materials can be formed into gaskets, seals or mechanical parts of every description. A typical application in the aircraft industry is the use of Silastic O-rings in a high-temperature shut-off valve which controls the intake of hot air from intermediate stages of jet engine compressors. The valves operate at 600 F under a pressure of 125 psi. Silicone rubber is used to seal bomb-bay doors, and the cover plates, doors and windows of camera bays in large bombers. These seals must retain their strength, resilience and flexibility at temperatures ranging from −100 to +160 F. Applications in other industries vary from the rings used to seal fluid transmission units on some automobiles to Silastic-covered rolls used in the hot or cold dip coating of fabrics, plastic film and metal sheeting or foil.

A new development by General Electric, 81267 primer liquid, now makes possible the design of bonded rubber-metal mechanical parts not previously practical. By use of this primer treatment on the desired surfaces, a bond between silicone rubbers and metals or ceramics stronger than the rubber itself can be produced. In this field, bonds have been made successfully to glass, ceramics, aluminum, steel, tin, and copper. The shear strength generally typical with bonds to steel is approximately 700 psi. This development now makes possible the design of engine and shock mounts that function equally well under extremes of temperature.

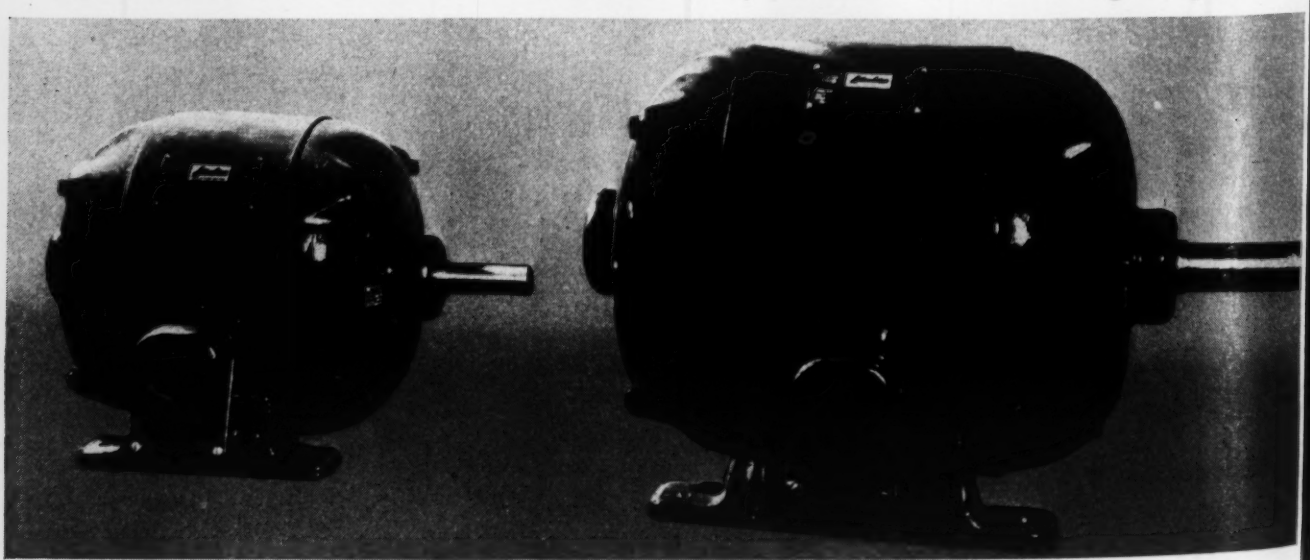
MISCELLANEOUS

FINISHES, INSULATIONS AND LUBRICANTS

Metallic Coatings: Several new and interesting developments in the field of metallic coatings have been reported recently. These are outlined in the following paragraphs.

COATINGS FOR ALUMINUM ALLOYS: New finishing processes have extended the useful range of aluminum and its alloys. The MHC finish, developed by Glenn L. Martin Co., produces a file-hard, heat-refractive and strongly bonded surface on cast or wrought aluminum alloys. The new electrochemical coating shows only half as much wear as case-hardened steel on the Taber abrasion tester and will stand up for one minute at 1800 F. Resistance to atmospheric and salt-water corrosion is excellent and the film serves as a good electrical insulator. Important applications include pistons, cylinders and jack-screws which would seize if uncoated, airplane thresholds and other parts requiring abrasion or wear resistance.

Fig. 50—Motor at left insulated with Class H silicone insulation has same rating as the one at the right insulated with convential Class A materials and withstands heavy overloads and continuous high temperatures



Electroplating of aluminum alloys has increased in importance. Substantial improvements in production procedures have broadened the field of applications. Electroplating on a zinc film produced on aluminum in a zincate solution, has been developed further. A uniformly colored gray zinc film is deposited by this method and over this copper is deposited. Any metal which can be plated over copper may be used for the final plating, nickel and chromium being common. In addition to decorative or corrosion-resistant finishes, hard chrome can be deposited on aluminum parts for heat and wear resistance.

COATINGS FOR MAGNESIUM ALLOYS: A new refractory ceramic coating for magnesium and magnesium alloys, the HAE coating, was recently developed at Pitman Dunn Laboratory, Frankford Arsenal, for U. S. Army Ordnance. Its outstanding characteristics are excellent corrosion resistance, high heat resistance, good dielectric strength, and high hardness. HAE can be applied to any of the commercial magnesium alloys, wrought or cast. It is applied electrolytically, much the same as aluminum alloys are anodized. Bond between the anodized coating and the magnesium is strongly adherent.

Probably the field in which this coating will produce the most revolutionary applications of magnesuim are those where corrosion resistance has been a limiting factor. Coated panels show no corrosion up to 90 hours exposure in salt-spray tests and no corrosion up to 4500 hours exposure in salt-spray tests when the coated surface is waxed.

Thickness of the coating is approximately 0.0010 to 0.0015-inch, depending on the length of time of treatment. A 1½ hour treatment will produce a thickness of approximately 0.0010 to 0.0012-inch, and thickness exceeding 0.0015-inch can be obtained as required. Build-up, or increase in thickness of the treated item is approximately 0.0008-inch per 0.0010-inch of coating per surface or approximately 80 per cent of the total coating thickness. For example, a piece of sheet magnesium coated on each side with 0.0010-inch of HAE would have an overall thickness increase of approximately 0.0016-inch.

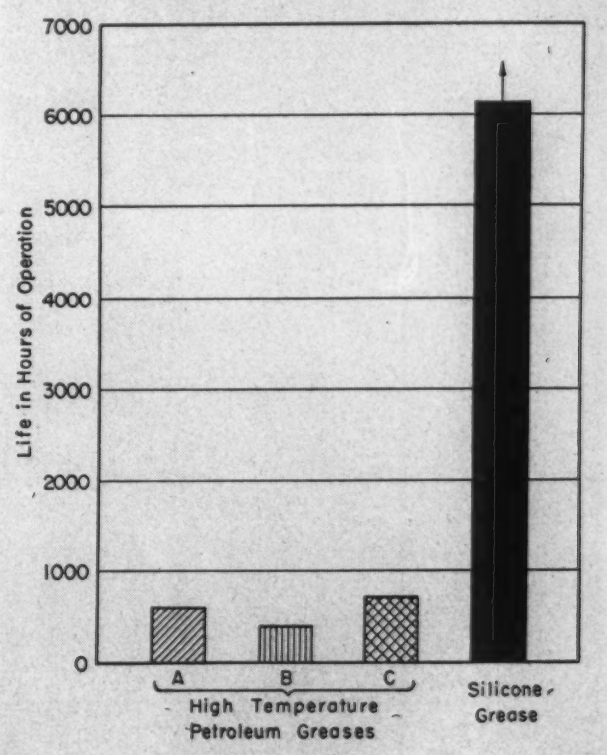
Abrasion test, using the Taber abraser, produced no breakdown of the HAE coating after 8000 cycles. By comparison, specimens having dichromate, alkaline dichromate, and galvanic anodize treatments showed a breakdown after 5 cycles. These latter treatments are not intended to increase the abrasion resistance and hardness of magnesium, but the comparative figures of 5 cycles and 8000 cycles indicate the relative hardness.

Hardness of the coating is between 7 and 8 on the Mohs scale. It can be used to polish steel having a Rockwell C hardness of 65. It will scratch glass and is about as hard as electrochemically deposited chromium. The fact that it can be applied in fairly thick coatings indicates it will support heavy unit compression loads even though the base material is soft.

HAE provides magnesium with a surface which is resistant to temperatures above 2500 F. Strength and modulus of elasticity of the coating are not yet

Fig. 51—Silastic (silicone rubber) insulated solenoid has 166 per cent of the capacity of an identical Class B coil plus maximum shock, abrasion and vibration resistance from −60 to 200 C

Fig. 52—Relative life of common motor bearing lubricants and Dow-Corning 44 silicone grease at 300 F



known. A 0.022-inch thick specimen of magnesium loses about 8 per cent of its tensile strength after 1½ hours treatment. Loss in tensile strength is proportional approximately to the thickness build-up of the treated specimen; i.e., approximately 80 per cent of the total coating thickness.

HAE is relatively inelastic, especially on the compression side of a bend. A sample of HAE-treated magnesium sheet can be bent and dented quite severely without visible damage to the coating on the tension side and without a complete break-through on the compression side. There is a visual flaking of a superficial layer on the compression side of the bend but not a complete break-through unless the radius of the bend is relatively sharp. HAE also appears to be chemically inert to most materials.

CORROSION AND HEAT-RESISTANT SURFACING: Bridging the gap between chromium plated ordinary steels and use of stainless steels is a new process called Chromizing developed in England. By a superficial alloying with chromium, this process converts the surface of ordinary steels into stainless steels. The chromium is diffused into the surface layers, chemically bonded and alloyed, and not plated on. The alloyed zone usually ranges from 0.002 to 0.010-inch in thickness and is approximately 50 per cent chromium content at the surface, decreasing inwards to zero (average content is 30 per cent).

Carried out in production somewhat like pack carburizing, the process consists in heating parts in a granular mixture, composed mainly of ferrochromium, under controlled atmosphere. The processing has no effect on dimensions.

Parts which have been produced with this treatment include jet engine blades, exhaust stacks, pump linings, burner parts, etc. For merely decorative purposes, this method is about half as costly as chromium plating. Original patents are held by Diffusion Alloys, Inc. of England and processing of parts there is carried out commercially by Metal-Gas Co., Ltd., a subsidiary of Colvilles, Ltd. The U. S. rights have been obtained by the Chromalloy Corp. of New York who are set up for full-scale production using the trade-name Chromalloy for the treatment.

Fig. 53—Ball bearings on drying cans of American Finishing Co. textile plant operate at 400 rpm in journals carrying saturated steam. Silicone grease gives some forty-five times the life of organic greases previously used in this application

Nonmetallic Finishes: In the long list of nonmetallic protective coatings are many which can help conserve scarce materials by imparting corrosion-resistant properties to ordinary materials.

SYNTHETIC BASE FOR PROTECTIVE FINISHES: A new baking-type coating intermediate that is expected to form a versatile base for a whole new field of protective finishes has recently been developed by General Electric. Designated as R-108, the coating is based on selected phenol derivatives and is compatible with a variety of coating resins. Properties of protective coatings formulated with R-108 combine the outstanding characteristics of both vinyl and conventional phenolic coatings—resistance to alkalies, acids, oxidizing agents, solvents, salts, and other corrosive chemicals over a wide temperature range; toughness, flexibility and abrasion resistance; and unusual stability to aging at elevated temperatures.

HOT LACQUER PROCESS: A relatively new technique is the hot-lacquer process developed by Hercules Powder Co. wherein the fluidity necessary for spraying is obtained by heating, with a resultant reduction in the amount of solvent necessary. Leading advantages claimed are improved quality of finish, fewer coats needed, and savings of both labor and materials.

ELECTROSTATIC PAINT SPRAYING: A new development in the application of paint, lacquer, enamel, and varnish finishes has been reported by the Ransburg Electro-Coating Corp. A special spray gun, with a cone-shape revolving head, is used to atomize and charge the paint. The electrostic field created by the revolving spray head transforms the paint particles

JOHNSON BRONZE

SLEEVE BEARING DATA

Bearing DESIGN

SLEEVE BEARING DATA

Standard Tests for Sleeve Bearings-1

IN the selection of the proper type of Sleeve Bearing for any given application there are certain fundamental steps to follow before arriving at the final decision. The first move is to determine, as near as possible, the operating requirements such as speeds, loads, shock, temperature, lubrication, etc. The next step is to compare, by certain known and accepted tests, which bearing *material* will meet these requirements in the most satisfactory manner. Samples of the various materials, each produced to the same size and thickness are then used so that each test is comparative. Thus by matching the operating requirements of the application to the physical properties of the bearing material we arrive at a satisfactory selection of the proper bearing to use.

In determining the physical properties of bearing materials we use the following tests:

Tensile Strength

The ultimate tensile strength is the maximum load per square inch the material will carry up to the point of rupture. It is really a test of toughness.

Yield Point

The yield point is the load in pounds per square inch necessary to produce an elongation of .2% of the original specified length.

Elongation

This property is expressed as the percentage of length increase, after test piece has been ruptured, divided by the original specified length. This test is an indication of the material's conformability property and in addition indicates to a certain degree the shock resisting capacity of the material.

Johnson Bronze Alloy No.	PHYSICAL PROPERTIES				
	Tensile lb. per sq. in. ±5000	Proportional Limit ±2000	Yield Point lb. per sq. in. ±3000	Elongation per cent in 2 in.	Brinell Hardness No.
19	27,500	7,800	20,700	8±4	62
25	22,500	6,900	16,750	11±4	44
27	30,000	9,700	19,000	10±5	58
29	24,000	7,600	16,400	9±4	52
51	36,500	12,500	18,500	15±5	67
53	36,000	13,000	19,000	18±4	69
55	39,200	13,600	21,000	10±5	74
66	26,000	7,800	14,500	12±5	48
71	29,000	8,200	16,500	20±7	49
72	29,000	8,600	14,600	17±5	56

A typical listing and comparison of various popular, cast bronze bearing alloys.

Reduction of Area

This property is determined by measuring the decrease which occurs in the cross sectional area of the specimen at the point of rupture, as compared to the original diameter of the test piece. This property is also expressed as a percentage.

Hardness

Hardness can be determined in several ways, with the Brinell and the Rockwell methods being the most popular in non-ferrous materials. In determining the Brinell hardness number we use a 10 millimeter ball and apply a 500 kilogram load for a period of thirty seconds. Hardness is, in fact, an indication of the material's resistance to deformation, which also indicates the compressive strength of the material.

Compressive Strength

This test establishes the percent of permanent deformation occurring under specified loads. It is figured in relation to the size and form of the specimen used for testing.

•

Engineering Service

Johnson Bronze offers manufacturers of all types of equipment a complete engineering and metallurgical service. We can help you determine the exact type of bearing that will give you the greatest amount of service for the longest period of time. We can show you how to design your bearings so that they can be produced in the most economical manner. As we manufacture all types of Sleeve Bearings, we base all of our recommendations on facts free from prejudice. Why not take full advantage of this free service?

•

This bearing data sheet is but one of a series. You can get the complete set by writing to—

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into charged particles that are strongly attracted to grounded workpieces. Very nearly complete and uniform deposition along with virtual elimination of over-spray effect considerable savings in paint. Need for spray booths, compressed air supply, etc., is obviated.

NEOPRENE COATINGS: There has been considerable progress lately in the development of neoprene coating solutions, especially with respect to the use of vulcanization accelerators for room temperature curing. Air-cured protective coatings, having most of the properties of heat vulcanized compositions, are now available. They are offered either as two-part combinations, one part of which contains the accelerator, or in single solutions containing all the necessary curing ingredients. Some recent applications are coating of plastic radar housings on jet airplanes to protect against rain erosion; coating of pump impellers and similar machine parts subject to abrasive wear; and maintenance coating for equipment exposed to corrosive atmosphere.

Electrical Insulation: In times such as these when the supply of important materials must be conserved as much as possible, more efficient materials provide the real, economical answer. Ability of silicone insulation to withstand temperatures 100 C above Class B limits has made it possible to increase the power per pound ratio by 50 to 100 per cent in motors, transformers, and solenoids, *Fig.* 50. Heat resistance of silicone insulation provides greater protection against heavy overloads and high ambient temperatures. One large chemical company which had several 50 and 60-hp Class A pump motors rewound with silicone insulation, found that the 50-hp motors are successfully withstanding peak loads of 86.5 hp in service.

Properly applied, silicone insulation has at least ten times the service life of the best insulating materials previously available. If excessive moisture is a problem it might be well to also note that silicone insulation also has ten times the wet insulation resistance of the best organic insulating materials.

SILASTIC ELECTRICAL INSULATION: Silicone insulation, available in the form described above, is composed of inorganic materials bonded and impregnated with silicone resins and varnishes. Recently, a second type of silicone (Class H) insulation made with Silastic (Dow silicone rubber) was announced. Silastic has always been recommended for insulating lead wire and for filling the voids in coils in the resinous type silicone insulation. Now, with the aid of new fabricating techniques it is possible to produce a pressure-sensitive Silastic tape ideal for insulating armature and field coils, solenoids, magnet and brake coils and transformer coils, *Fig.* 51. Properly applied, the Silastic tape vulcanizes to form a void-free jacket that is moisture proof, stable and resilient at Class H operating temperatures (180 C) and highly resistant to oil and to both mechanical and electrical fatigue.

Silastic tape has twice the thermal conductivity of conventional resinous dielectrics. In a solenoid coil, for example, Silastic gives 15 per cent more capacity than resinous Silicone (Class H) Insulation at 180 C. One of the first and most successful applications for Silastic tape is in the insulating of main and interpole field coils in diesel-electric traction motors. Over 4200 such coils have been insulated with Silastic tape. Many have been in service for more than 15 months with no failures reported even in the case of one locomotive that was suddenly thrown into reverse by a short-circuited control panel. Class H Insulation made with Silastic tape has about the same life expectancy as resinous silicone insulation.

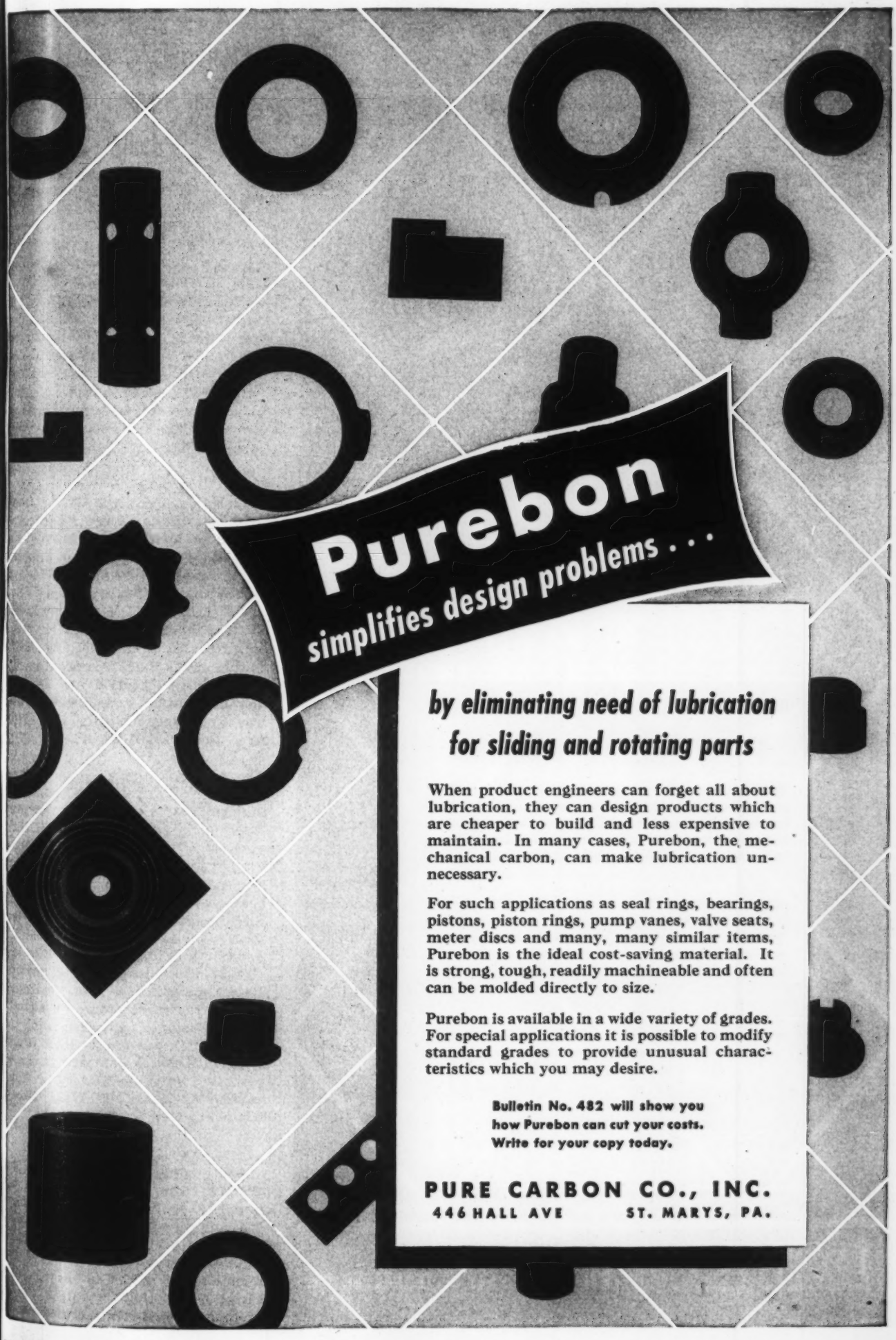
Machine Lubricants: Recent development in grease lubricants also embrace the silicones. Broadening the ambient-temperature duty area of lubricants to new highs and lows, *Fig.* 52, these new materials should be of considerable interest as adjuncts to the silicone oils now available.

Silicone greases are designed for use in bearings and valves exposed to high and low temperatures or corrosive atmospheres. In general, these greases possess the same unique properties characteristic of all silicones and, therefore, remain stable over a wide temperature range. Several types of silicone greases are available to provide proper lubrication at temperatures varying from −100 to 500 F and at bearing speed factors up to 225,000. Good lubricity combined with low volatility, freedom from gumming or sludging and general inertness are other advantages of silicone greases.

Applications for silicone greases vary from the trolleys in oven conveyor systems to the gears of X-ray machines; from Stellite-treated valves handling extremely hot hydrocarbon gases to microphone switches. One silicone grease designed for the lubrication of ball bearings operating at temperatures ranging from −40 to 350 F is making permanent lubrication a practical reality. For example, in a large textile finishing plant, *Fig.* 53, this silicone grease has had at least forty-five times the life of the organic grease previously used to lubricate the ball bearings of drying cans operating at 400 rpm. This long service life is the exception rather than the rule. Laboratory and field testing indicate about ten times longer service with this silicone grease.

Sealed ball bearings prelubricated with this grease are available now from several leading bearing manufacturers. They are expected to give five years of service without relubrication in high-temperature electric motors.

Acetylene Tetrabromide: A heavy (2.95 specific gravity) nonflammable liquid, acetylene tetrabromide produced by the Dow Chemical Co. is being used as a vibration damper in the spinning mechanism of an automatic home washer. It is also being used as the liquid medium in level gages and as a nonflammable solvent.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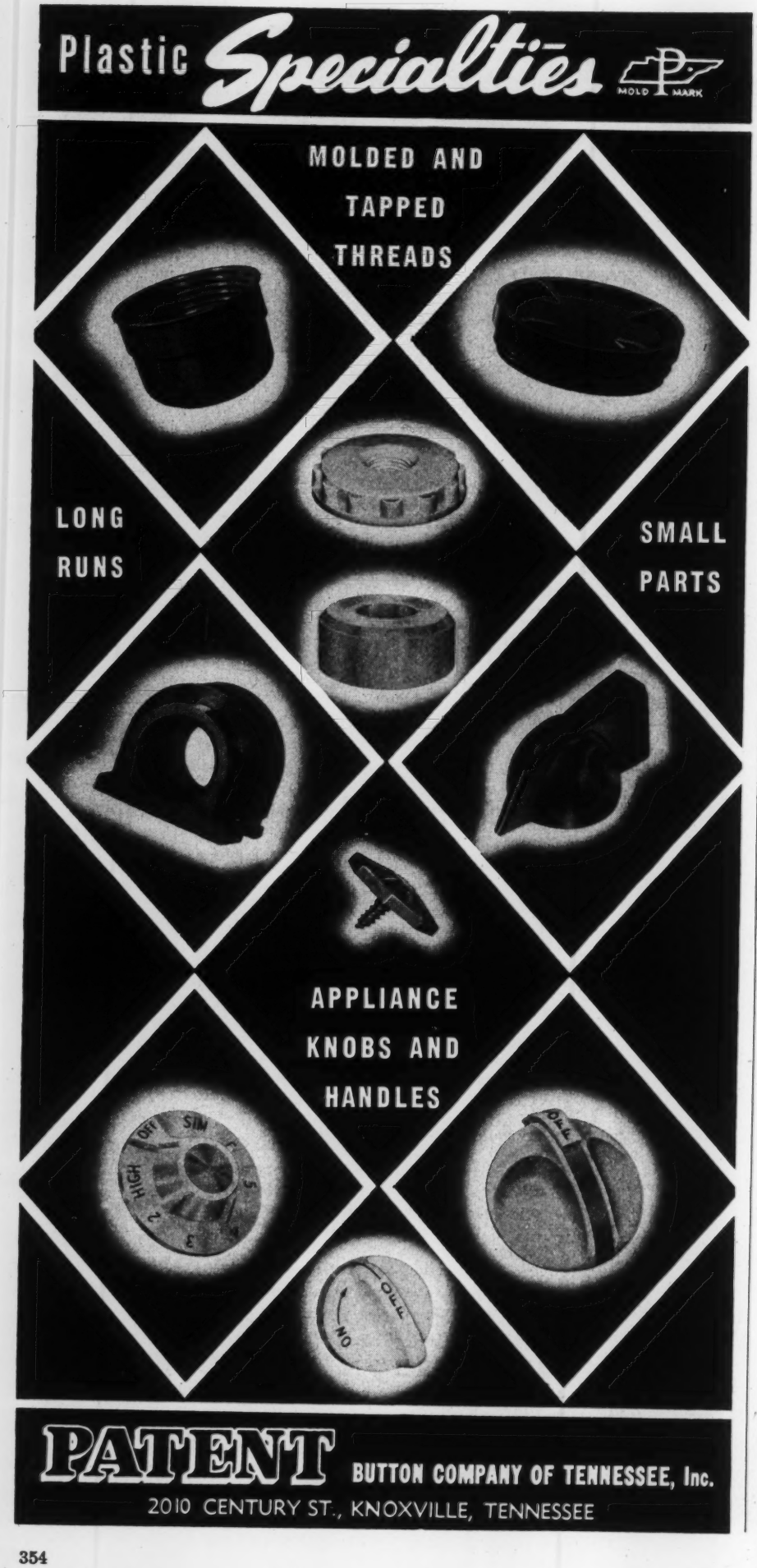


Materials Specification and Standardizing Bodies

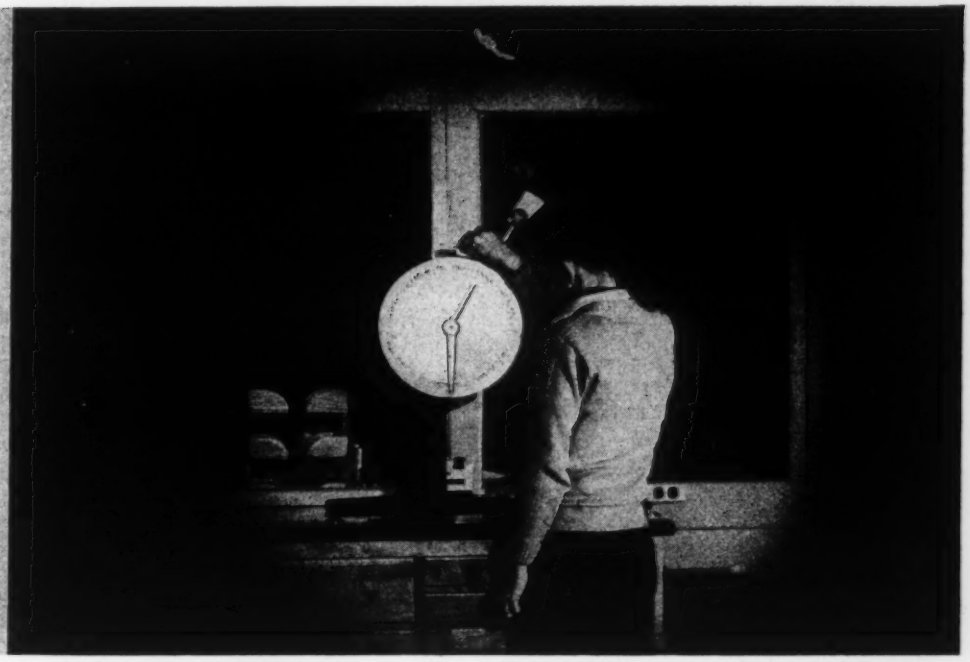
NUMEROUS groups are activ in standardizing and promu gating the standardization engineering materials. Owing to th tempo of industrial output and th rapid developments in materials, becomes imperative that designers b conversant with the work of thes standardizing bodies. The major ac tive groups whose specifications ar widely employed are briefly covered in the following paragraphs. To per mit securing necessary specifications without delay, addresses and details are given for each.

AMERICAN IRON AND STEEL INSTITUTE: Standards of the AISI covering steels appear in a manual entitled *Steel Products Manual,* which is published in sections devoted to each form of material produced—hot-rolled carbon steel bars, alloy steels, etc. The numbering system for steels used by AISI is essentially the same as that of the SAE. To purchase copies of this publication and for further information write the American Iron and Steel Institute, 350 Fifth Ave., New York 1, N. Y.

SOCIETY OF AUTOMOTIVE ENGINEERS: Standards of the SAE cover most basic engineering materials. Details concerning SAE materials designations, chemical compositions and, in some cases, physical properties and heat treatments are covered in the *SAE Handbook.* In addition, the Aeronautics Division of the SAE issues the Aeronautical Materials Specifications (AMS) which are complete procurement specifications for materials used in the manufacture of aircraft, aircraft engines, propellers, and accessories. Copies of the *SAE Handbook* and AMS specifications can be purchased from the Society of Automotive Engineers, 29 West Thirty-Ninth St., New York 18, N. Y.

AMERICAN SOCIETY FOR TESTING MATERIALS: The ASTM standards are complete procurement specifications containing data on chemical composition and detail requirements. Completely up-to-date references are maintained by ASTM in the form of a set of Handbooks, the *ASTM Standards,* published trienially. Between

as seen in National's Research Laboratories, raw materials and finished products are constantly checked for performance standards.



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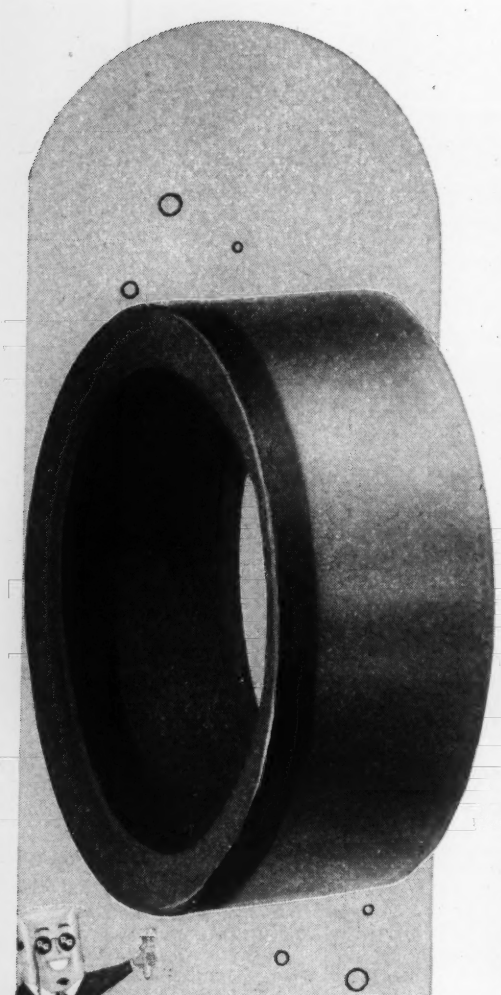

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The illustration at the left shows the heat-resistant seal used in coupling the metallic hose that carries live steam from car to car of America's passenger trains. Fabricated by Roth engineers to the exacting specifications of the Vapor Heating Corporation, more than 500,000 of these heat-resistant rubber seals are now in service. Since 1923, Roth has successfully served Vapor Heating Corporation's exacting requirements for molded rubber parts.

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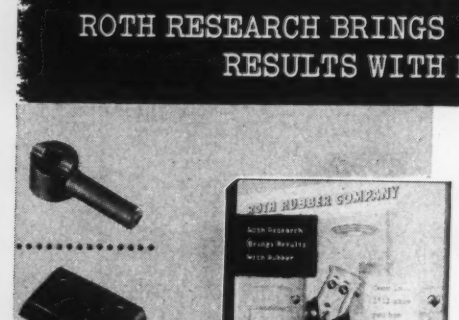

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publications, supplements and tentative standards are issued. The books of the standards are as follows: Part 1—Ferrous Metals; Part 2—Nonferrous Metals; Part 3—Cement, Refractories, Ceramics, Thermal Insulation, Concrete, Road Materials, Waterproofing, Soils; Part 4—Paint, Naval Stores, Wood, Adhesives, Paper, Shipping Containers; Part 5—Textiles, Soap, Fuels, Petroleum, Aromatic Hydrocarbons, Water; Part 6—Electrical Insulation, Rubber, Plastics. For information or purchase of the standards write to the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

FEDERAL AND MILITARY SPECIFICATIONS: Today, the Munitions Board Standards Agency approves and promulgates all U. S. Government specifications. Succeeding the Joint Army and Navy Specifications Board (JAN), the new Standards Agency is proceeding with the task of co-ordinating all military specifications—Army, Navy and Air Force—into a single military series with the symbol MIL. This is expected to be completed by July 1955. Until this job is complete and to provide for immediate procurement when time for co-ordination is not available, there will be two types of military specifications: co-ordinated and interim. Interim specifications are mandatory for the department issuing them; permissive for others.

To simplify the problem of locating and obtaining information on any required standard, the Standards Agency is issuing a *Military Index* covering all the military specifications formerly contained in seventeen indexes. The index consists of four volumes:

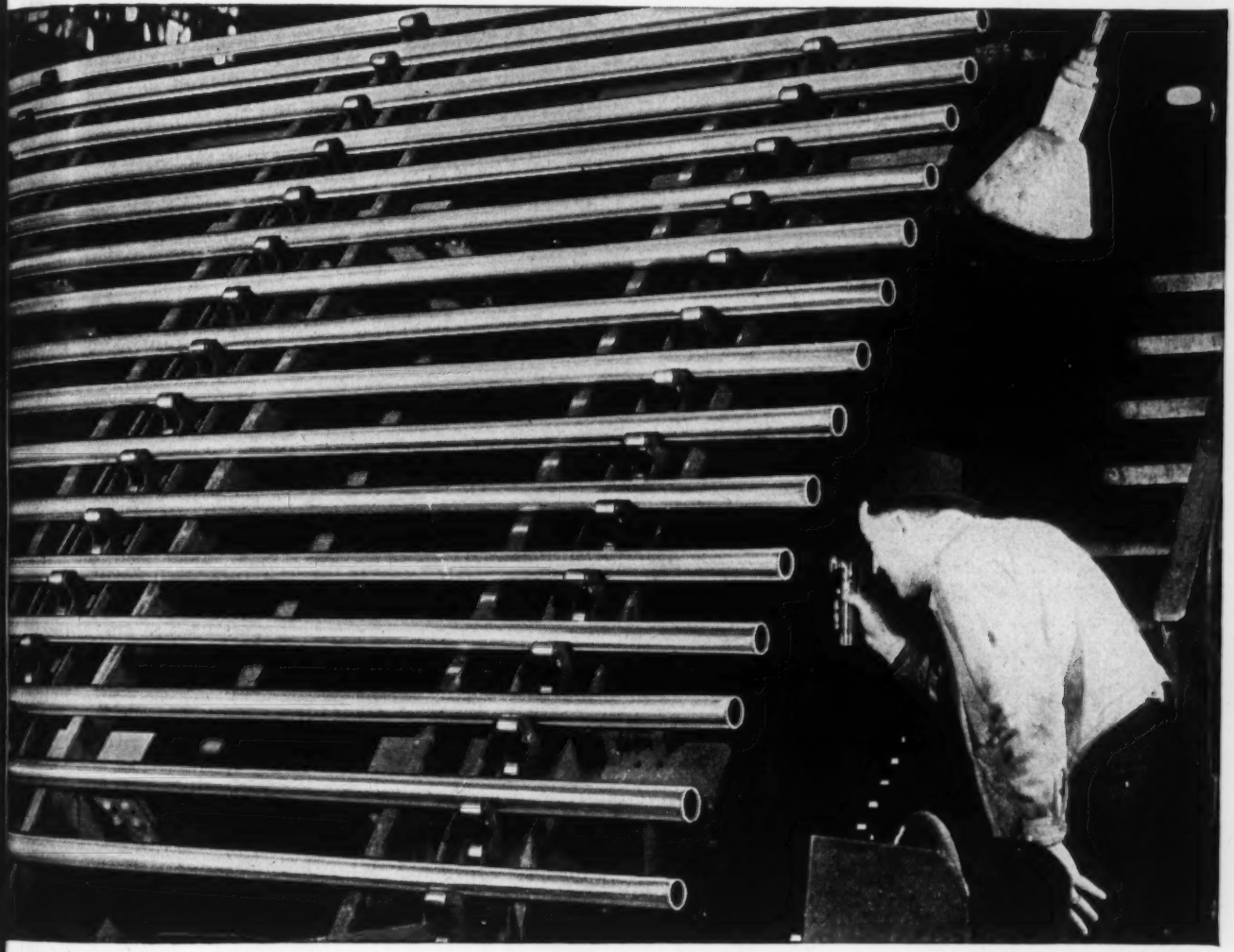
Volume I—Munitions Board: Listing of all MIL specifications and standards.

Volume II—Army: Listing of all specifications and standards used by the U. S. Army.

Volume III—Navy: Listing of all specifications and standards used by the Navy departments.

Volume IV—Air Force: Listing of all specifications and standards used by the U. S. Air Forces.

This index will be issued semiannually and will have monthly supplements to maintain the volumes current. Along with the present *Federal Index,* it should furnish any needed information about Department of Defense specifications. Copies of the *Military Index* (price each volume $2.75) and the *Federal Index* (price $0.35) can be obtained from the Superintendent of Documents



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2 Chrome 1/2 Moly • 2-1/4 Chrome 1 Moly
5 Chrome 1/2 Moly • 7 Chrome 1/2 Moly
9 Chrome 1 Moly
A1S1 1335 • A1S1 2317 • A1S1 2512 • A1S1 4130, 4140 • A1S1 4615 • A1S1 8615, 8620, 8630, 8635, 8640 • 7% Ni. • 9% Ni.

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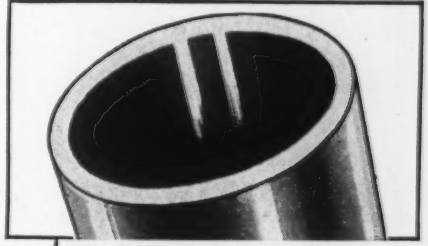

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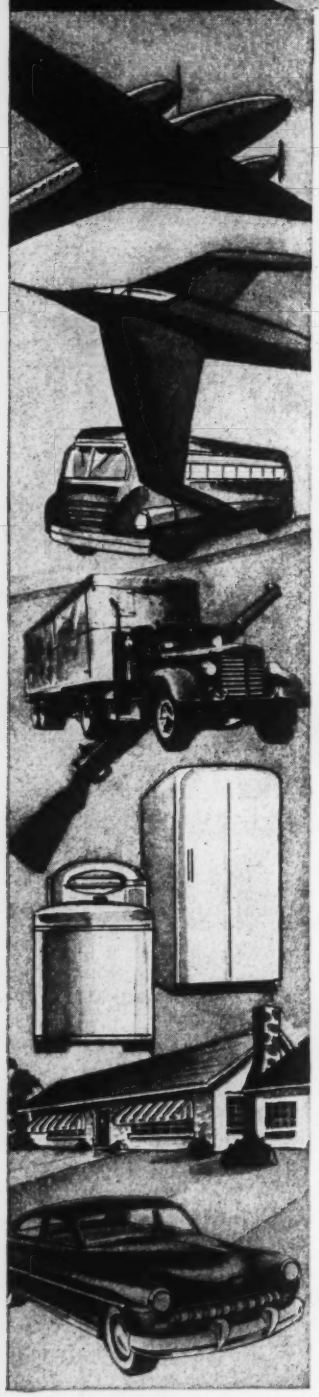
TO MAKE YOUR PRODUCT DURABLE



PAINT BONDING

"GRANODINE"® forms a zinc-iron phosphate-coating bond on sheet metal products—automobile bodies and fenders, refrigerator cabinets, etc.—for a durable, lustrous paint finish.

"LITHOFORM"® makes paint stick to galvanized iron and other zinc and cadmium surfaces.

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The oiled "THERMOIL-GRANODINE" coating on pistons, piston rings, cranks, camshafts and other rubbing parts, allows safe break-in operation, eliminates metal-to-metal contact, maintains lubrication and reduces the danger of scuffing, scoring, galling, welding and tearing.

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AMERICAN CHEMICAL PAINT COMPANY

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For specific procurements under contract, copies of military specifications and standards required should be obtained from the procuring agency awarding the contract, or as directed by the contracting officer. For noncontractors, however, requests for specifications should be addressed as follows:

Department of the Air Force
Air Adjutant General
Publishing Division
Pentagon Building
Washington 25, D. C.

Department of the Army
Chief of Engineers
Attention: Administrative Service Division
Washington 25, D. C.

Department of the Navy
Bureau of Supplies and Accounts
Washington 25, D. C.

General questions on specifications and standards may be addressed to the Director, Munitions Board Standards Agency, Washington 25, D. C.

New Materials Producers

Collaboration of the following organizations in the preparation of this article is acknowledged with appreciation:

Aluminum Co. of America ..... Pittsburgh, Pa.
American Brass Co. ..... New York 4, N. Y.
American Iron & Steel Institute ..... 350 Fifth Ave., N. Y.
Americal Lava Corp ..... Chattanooga 5, Tenn.
Armco Steel Corp. Middletown, Ohio

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Carpenter Steel Co. ... Reading, Pa.
Chase Brass & Copper Co. Inc. ..... Waterbury 20, Conn.
Connecticut Hard Rubber Co. ..... New Haven 9, Conn.
Continental-Diamond Fiber Co. ..... Newark, Delaware
Corning Glass Works Corning, N. Y.
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on land, sea and in the air

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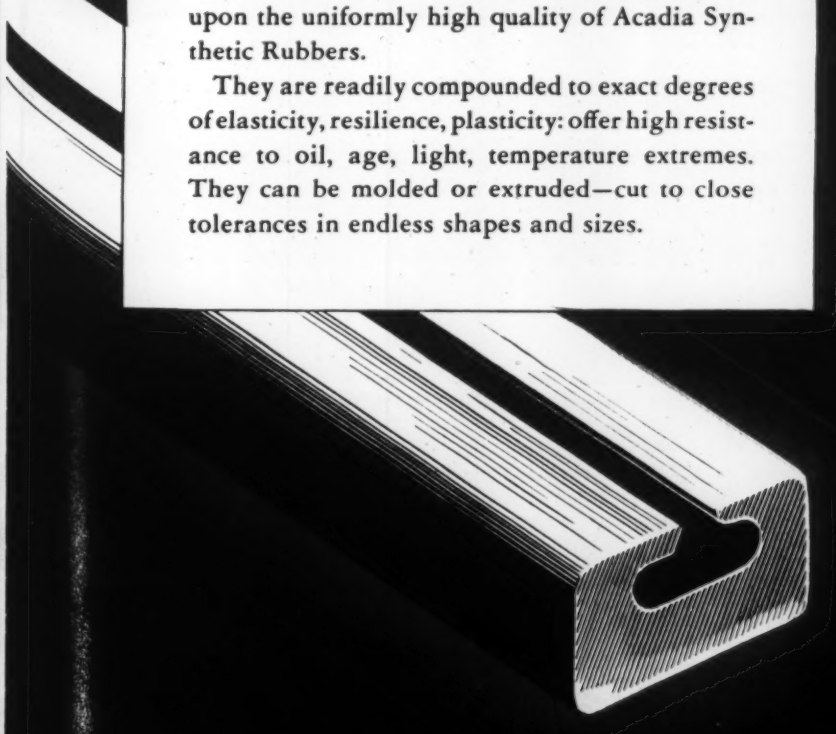
They are readily compounded to exact degrees of elasticity, resilience, plasticity: offer high resistance to oil, age, light, temperature extremes. They can be molded or extruded—cut to close tolerances in endless shapes and sizes.



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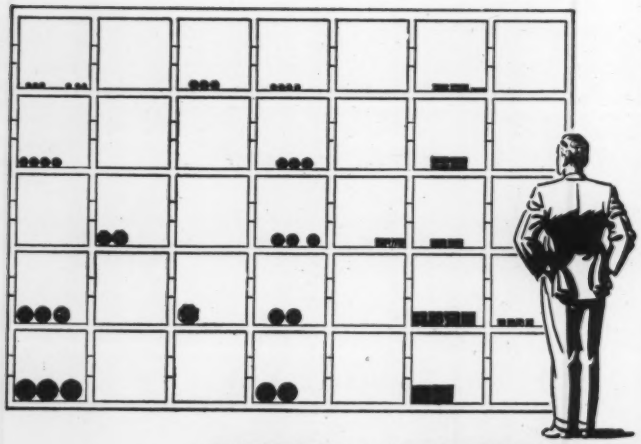

The present serious STEEL SHORTAGE

has reduced our warehouse stocks of HY-TEN and Standard alloy steels to a sub-normal level.

This inventory situation is, of course, very unsatisfactory but we are doing everything we possibly can to improve it.

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Your nearby Wheelock, Lovejoy representative knows metallurgy. He stands ready to give you expert assistance in solving your problems.

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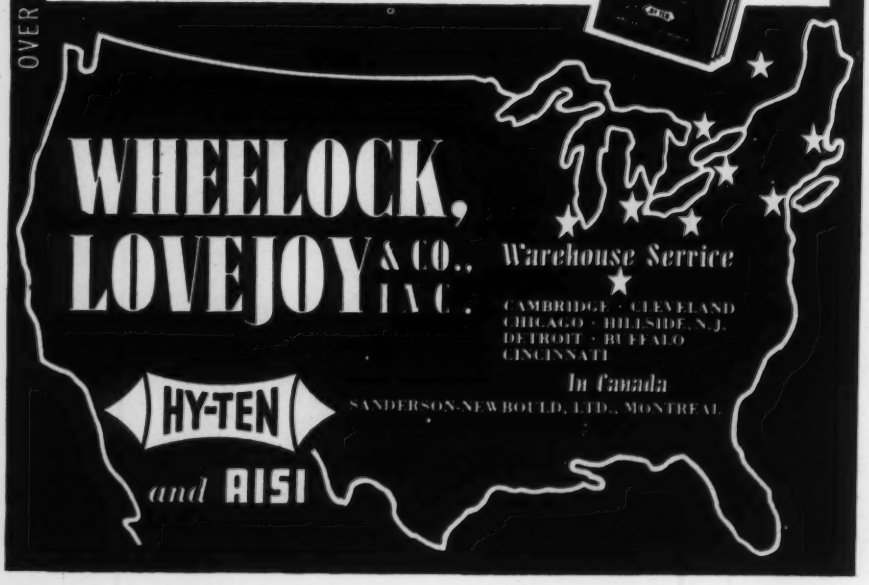

Miscellaneous—Group II-E

(In approximate balance)

Asbestos, Chrysotile: Shingle and paper fibers
Mica, phlogopite, block:
Muscovite block and film (stained and poorer)
Muscovite splittings
Paper
Paperboard
Quartz crystals (MBS Grades I and II)
Talc: Ground, including steatite

Miscellaneous—Group III-E

(In fair to good supply)

Asbestos, Chrysotile:
Shorts and waste fibers
Clays: Ball, fire and china
Reclaimed rubber

Copies of the complete *List of Basic Materials and Alternates* may be had from the nearest District or Regional Office of the Department of Commerce.

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Shape of things to come...

From Your Blueprint . . . to Your Product

OSTUCO TUBING

Tapering • Swaging • Flanging • Bending
Upsetting • Expanding • Reducing • Beading
End closing • Spinning • Drilling • Slotting
Notching • Flattening • Shaping • Trimming
Threading • Angle Cutting • And Many Others

Products for the future take shape on the drawing boards of today. And scores of manufacturers are planning ahead for the time when emphasis will again be on production of consumer goods.

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Because of the continuing needs of the military services, we cannot always promise early delivery estimates on new civilian orders. However, our experienced tubing engineers are at your service now to help give your product a future with OSTUCO Steel Tubing.

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Manufacturers and Fabricators of Seamless and Electric Welded Steel Tubing
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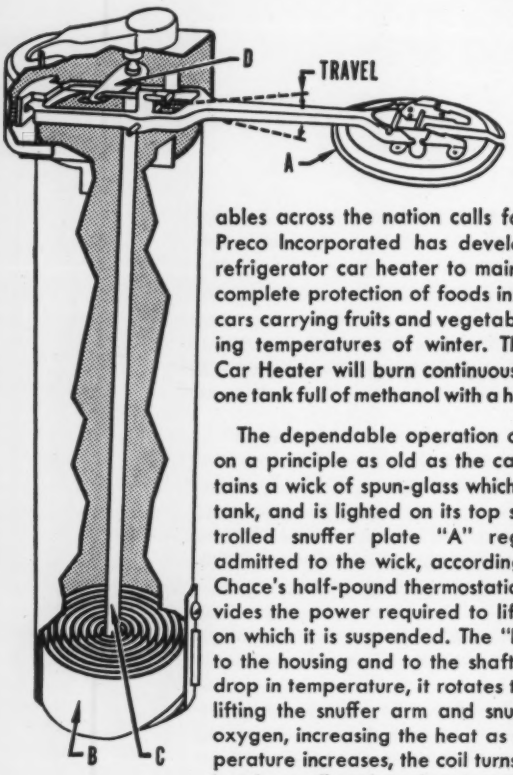

The transportation of perishables across the nation calls for ingenuity to prevent spoilage. Preco Incorporated has developed this safe methanol-burning refrigerator car heater to maintain the proper temperature for complete protection of foods in the endless trains of refrigerator cars carrying fruits and vegetables across the country in the freezing temperatures of winter. The Preco Automatic Refrigerator Car Heater will burn continuously at full flame for fifty hours on one tank full of methanol with a heat output of 6000 BTU's per hour.

The dependable operation of this automatic heater is based on a principle as old as the candle snuffer. A central tube contains a wick of spun-glass which draws up the methanol from the tank, and is lighted on its top surface. The thermostatically controlled snuffer plate "A" regulates the amount of oxygen admitted to the wick, according to the temperature in the car. Chace's half-pound thermostatic bimetal coiled element "B" provides the power required to lift the snuffer plate and the arm on which it is suspended. The "heat motor" element "B" is fixed to the housing and to the shaft "C". As the bimetal reacts to a drop in temperature, it rotates the shaft with lever "D" attached, lifting the snuffer arm and snuffer plate, exposing the wick to oxygen, increasing the heat as required. If the surrounding temperature increases, the coil turns in the opposite direction, lowering the snuffer plate, leaving only a pilot flame.

This largest of all Chace thermostatic bimetal elements is fabricated to Preco specifications from Chace #6650, one of the 29 types available in strips, random length coils or complete elements. Our 64-page reference on the selection and design of thermostatic bimetal elements for temperature responsive devices may guide you in the development of your own products. Before your new design progresses to the tooling stage, however, be sure to consult the Chace Applications Engineers for the advice of qualified experts.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

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ELECTRUNITE TUBING *Eases Life-*

FOR THE MANUFACTURER...

FOR THE PATIENT...

HOSPITAL PATIENTS can relax in every position, from full-reclining to upright, in this sturdy rejuvenating chair made by Barcalo Manufacturing Company. Steel tubing provides the stiffness and rigidity to make the chair steady and reassuring to the patient, yet light to move.

The manufacturer likes the way ELECTRUNITE Steel Tubing works on this application. Uniform ductility and wall thickness assure rapid, predictable forming and bending of the tubes to shape. Where tube ends must be fully flattened at joints, there's no trouble with cracks and fractures. The excellent surface of this ELECTRUNITE Tubing requires no special handling or trick treatments to hold long-lasting finishes under severe service.

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REPUBLIC STEEL CORPORATION
STEEL & TUBES DIVISION
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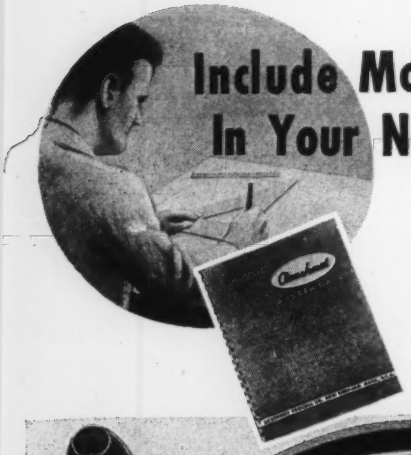
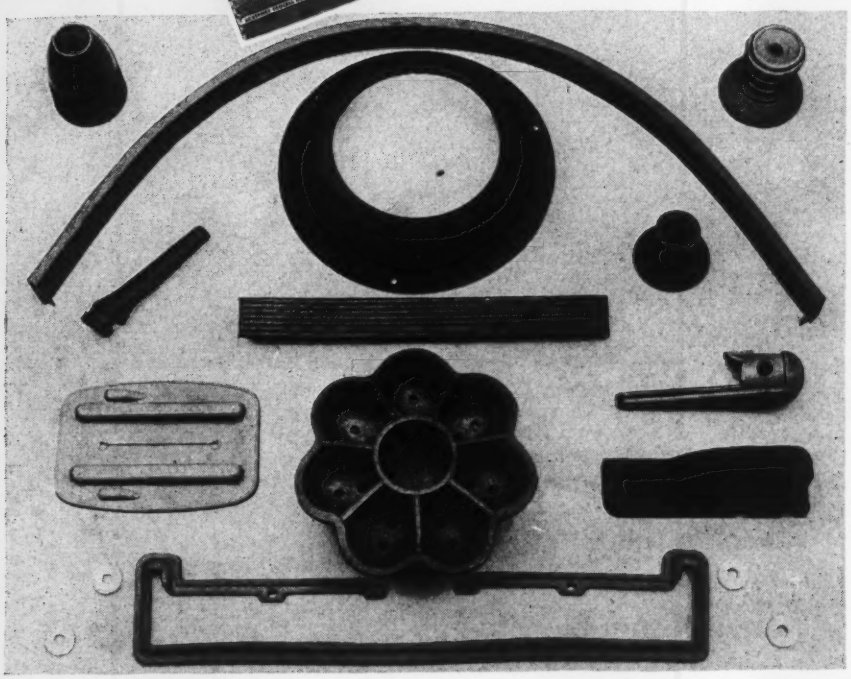
ELECTRUNITE TUBING



Include Molded RUBBER Parts In Your New Product Designs

Write for a copy of the ACUSHNET RUBBER HANDBOOK. It contains helpful information, specifications, natural and synethetic rubber data, etc. Please make request on company letterhead.



When designing new products, or re-designing the old, consider the unlimited applications in which molded rubber now excels. Meeting functional specifications and multiple requirements beyond the limits of other materials, rubber gives the designer a welcome release from age-old restrictions.

ACUSHNET has worked with many customers in the initial stages of their designs when the collective specialized knowledge of our laboratory and engineering staffs has aided in obtaining the most satisfactory material, mold design and price. Our laboratory facilities are available to customers for the development of designs and compounds.

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PROCESS COMPANY
New Bedford, Mass., U. S. A.

Address all communications to 762 Belleville Ave., New Bedford, Mass.

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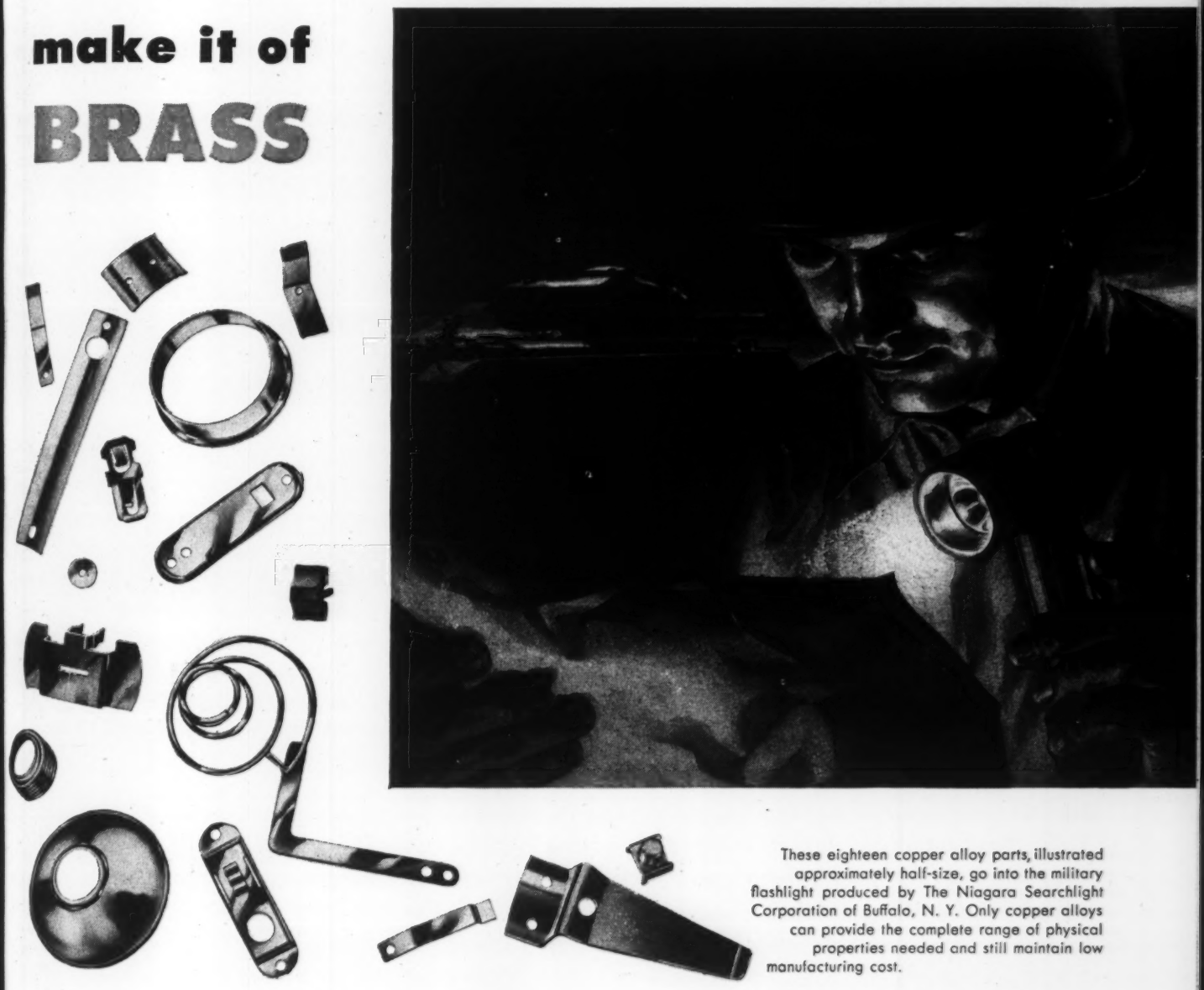
to turn a production problem into a LIGHT subject—

make it of BRASS



These eighteen copper alloy parts, illustrated approximately half-size, go into the military flashlight produced by The Niagara Searchlight Corporation of Buffalo, N. Y. Only copper alloys can provide the complete range of physical properties needed and still maintain low manufacturing cost.

If, like this military flashlight, your product consists of parts calling for certain physical properties . . . if it must be born of a streamlined manufacturing budget and still be an aristocrat in quality—then you'll find no metal more versatile than brass.

Although almost all of these 18 metal parts differ in their function, copper alloys supply the required properties – high electrical conductivity, resilience, excellence as a plating base, strength, immunity to rust and resistance to corrosion. And to all these properties, singly or in combination, add the characteristic that brass can be fabricated more economically by more methods than any other metal.

With all these properties, brass has no equal for its usefulness as a manufacturing metal. Brass is the metal on which your designers, cost analysts, production men and sales department will be most likely to agree.

Our Technical Department will gladly suggest the copper alloy best suited to your product and manufacturing methods. Just write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

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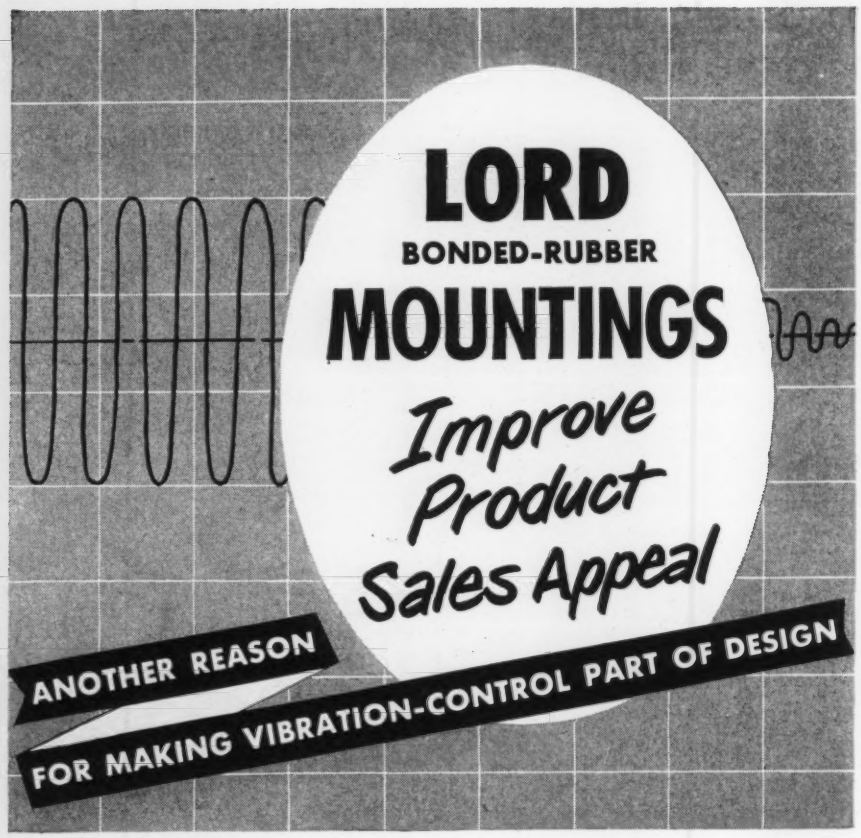
ANACONDA® *the name to remember in*

COPPER
BRASS
BRONZE



● The primary function of LORD Mountings is to isolate vibration. When this is accomplished machines and equipment operate with higher efficiency . . . run smoother, quieter . . . service life is lengthened. Personnel fatigue is reduced . . . production increased . . . scrap losses diminished . . . maintenance costs lowered.

All these important factors mean added sales appeal, and you will improve your product sales appeal by eliminating costly, nerve-racking vibration and noise. LORD Mountings protect equipment from either internal or external vibration.

Vibration-control should be planned as an integral part of your product. LORD Engineers will assist you to most effectively adapt flexible mountings to your designs . . . select mountings of proper type, size, and deflection . . . position the mountings for greatest effectiveness.

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LORD MANUFACTURING COMPANY, ERIE, PA.

LORD BONDED RUBBER — *Vibration-Control Mountings . . . Bonded-Rubber Parts*

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SO HIGH A FINISH...

NEED CYLINDER PARTS? New Rockrite Tubing comes with so high an inside finish that it is ready to go to work as hydraulic cylinders, shock absorbers and similar parts. Smooth, scratch-free inner surface requires *no machining* when used with leather or other soft packings. Only a light honing is needed for metal piston rings.

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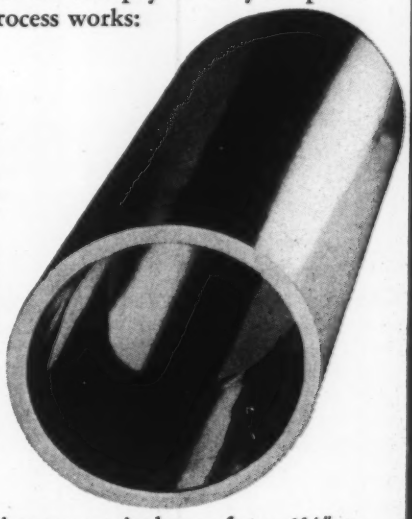
- Dies compress the metal against a mandrel, tending to iron out small irregularities on both the inside and outside surfaces. The metal flows from high spots in the same manner as when it is forged.
- A certain amount of planishing action also takes place on the inside surface of the tube as it elongates under the pressure of the dies and creeps forward while in contact with the mandrel.
- In no part of this operation is there any action which can produce longitudinal scratches. The metal is not drawn through a die and over a mandrel.



SIZES? Rockrite cylinder-finish tubing comes in bores from 1½" to 5½", depending on wall thickness. Get additional facts and figures from Joseph T. Ryerson & Sons Company, Chicago, national warehouse distributor, or write us direct.

ROCKRITE saves more than any other tubing

- Higher cutting speeds
- Tools last longer between grinds
- Work-surface finishes are better
- Machined parts have closer tolerances
- Stations on automatics are often released for additional operations
- Extra-long pieces available — less downtime for magazine stocking and fewer scrap ends
- Closer tolerances often eliminate necessity for machining on outside or inside

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